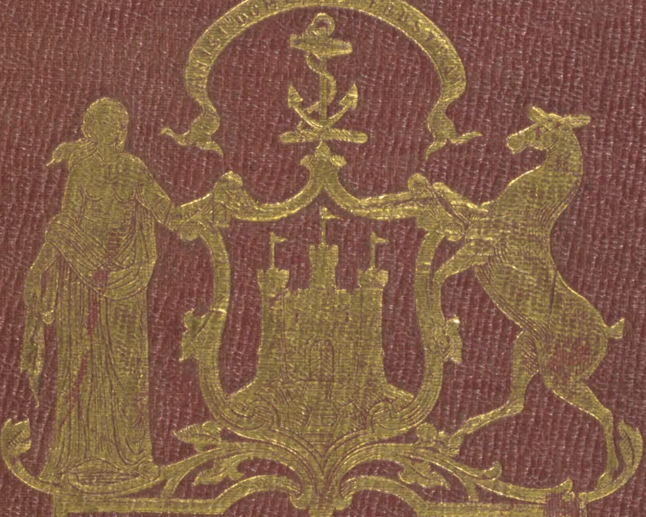

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MAGNETISM.

History.

The word magnetism is derived from the Greek word μάγνης, a name given to the *loadstone*, or *native magnet*, an ore of iron well known to the ancients. The term μάγνης itself is said to be derived from one *Magnes*, a Greek shepherd, who observed on Mount Ida the attractive power which the loadstone exercised upon his iron crook. The most probable supposition, however, is that it took its name from *Magnesia*, a country in Lydia, where it was first discovered; and this conjecture is confirmed by the fact that the magnet was often called by the ancients *Lapis Heracleus*, from *Heraclea*, the capital of *Magnesia*.

The science of magnetism treats of the phenomena exhibited by magnets, whether natural, like the loadstone, or artificial, like bars of steel to which magnetism has been permanently communicated; of their reciprocal action upon each other; of the laws of the forces which they develop; of the methods of making artificial magnets; and of the magnetic phenomena exhibited by our globe.

In giving an account of this interesting science in modern times, we shall adopt the following arrangement:—

1. On the history of magnetical discovery.
2. On the general phenomena and principles of natural and artificial magnets.
3. On the magnetism of bodies not ferruginous.
4. On the development of magnetism in bodies by rotation.
5. On the influence of heat on magnetism.
6. On the action of iron spheres on the needle.
7. On the influence of magnetism on chemical action.
8. On the laws of magnetic forces.
9. On terrestrial magnetism.
10. On the different methods of making artificial magnets.
11. On magnetical instruments and apparatus.
12. On the theories of magnetism.

CHAP. I.—ON THE HISTORY OF MAGNETICAL DISCOVERIES.

The attractive power of the natural magnet or loadstone over small pieces of iron seems to have been known from the remotest antiquity. It is distinctly referred to by Homer, Pythagoras, and Aristotle. Pliny mentions a chain of iron rings suspended from one another, the first being upheld by the loadstone; and he relates that Dinocares proposed to Ptolemy Philadelphus to build at Alexandria a temple, the vault of which, crowned with loadstones, should suspend in the air an iron statue of Queen Arsinöe. St Augustin likewise makes mention of a statue suspended in the air in the temple of Serapis at Alexandria.

History.

Invention of the compass.

In his description of China, Duhalde has stated that the directive power, or polarity of the magnet, was known to the Chinese in the earliest ages, and that the needle had been employed to guide travellers by land a thousand years before Christ; and it is stated by Humboldt, that, according to the *Peuthsaoyani*, a treatise on Medical Natural History, written 400 years before Columbus, the Chinese suspended the needle by a thread, and found it to decline to the S.E., and never to rest at the true S. point.

Although the common properties of the loadstone were known to the ancients, and were no doubt studied even during the dark ages, yet, notwithstanding the claims of the Chinese and Arabians, the directive power of the loadstone, or of a needle touched or rubbed by it, seems to be the discovery of modern times. Are Frode, an Icelandic historian, who was born in 1068, mentions in his *History of the Discovery of Iceland*, that Floke Vilgerderson departed from Rogoland, in Norway, to seek Gadersholm, or Iceland, some time in the year 868. He carried with him three ravens as guides; and, to consecrate them for this purpose, he offered up a sacrifice in Smörsund, where his ship lay. "*For*," says Frode, "*in those times seamen had no loadstone in the northern countries.*" A.D. 868.

A Chinese philosopher, Keoutsoung-chy, who wrote works on natural history about A.D. 1111, observes, that the magnetic needle declines towards the E., and is $\frac{5}{6}$ths to the S.

That the mariner's compass was known in the twelfth century, about the year 1150, is proved by notices of it in various authors, particularly in an old French poem called *La Bible Guyot*, which is contained in a curious quarto manuscript of the thirteenth century, still existing in the Royal Library at Paris. Guyot of Province, the author of this poem, was alive in 1181. After referring to the ways by which navigators are guided in their course, and mentioning the pole star, he adds,—

Un art font qui mentir ne peut,
Par la vertue de la marinière,
Un pierre laide et brunière
Où le fers volontiers se joint,
Ont regardent lor droit point.

A.D. 1200.

Cardinal James de Vitri, who flourished about the year 1200, mentions the magnetic needle in his history of Jerusalem; and he adds, that it was of indispensable utility to those who travelled by sea.

That the mariner's compass was known to the northern nations in 1266, appears from Torfæus's *History of Norway*, where it is mentioned, that Jarl Sturla's poem on the death of the Swedish count Byrgeres was rewarded with a mariner's compass. The directive property of the magnet is also distinctly mentioned in an epistle of Petrus Peregrinus de Marcourt, written about the latter end of the thirteenth century. This letter was addressed "Ad Sigerium de Foueancourt militem de magnete." This epistle contains a description of the loadstone, the means of finding its poles, and its property of attracting iron; and it proves that *the part of the magnet which is turned to the N. attracts that which is turned to the S.*

Paulus Venetus. A.D. 1260.

Peter Adsiger. A.D. 1269.

A Neapolitan, named Flavio Gioia, who lived in the thirteenth century, has been regarded by many as the inventor of the compass. Dr Gilbert affirms that Paulus Venetus brought the compass from China to Italy in 1260. Ludi Vestomannus asserts, that about 1500 he saw a pilot in the East Indies direct his course by a magnetic needle like those now in use. One of the earliest treatises on magnetism is a Latin letter of Peter Adsiger, written in 1269, contained in a volume of manuscripts in the library of the University of Leyden. This letter, which appears to have been written for the instruction of a friend, is in reality a methodical treatise, in two parts, the first of which is subdivided into ten, and the second into three chapters. In the second chapter of the second part, the mariner's compass, and the method of constructing it, are clearly described; and, what is still more interesting, the author not only mentions the declination of the magnetic needle, but had observed its actual deviation from the meridian. "Take notice," says he, "that the magnet, as well as the needle which has been touched by it, does not point exactly to the poles; but that part of it which is reckoned to point to the S. inclines a little to the W., and that part which looks towards the N. inclines as much to the E. The exact quantity of this declination I have found, after numerous experiments, to be *five degrees*. However, this declination is no obstacle to our guidance, because we make the needle itself decline from the true S. by nearly one point and a half towards the W. A point, then, contains five degrees." Mr Christie seems to consider the authenticity of this manuscript as doubtful, because no new observation of the declination seems to have been made for two centuries afterwards; and because the declination should be westerly in place of easterly in 1269, according to the best law of the change which can be deduced from subsequent observations.

Columbus. A.D. 1492.

Variation discovered.

The declination, or the variation of the needle, thus distinctly described by Adsiger, if his manuscript is authentic, must be considered as well known before the time of Columbus, to whom the discovery of it has been generally ascribed. His son Ferdinand states, that on the 14th of September (13th according to Washington Irving) 1492, his father, when about two hundred leagues from the island of Ferro, noticed for the first time the variation of the needle; "a phenomenon," says Irving, "which had never before been remarked." "He perceived," adds this author, "about nightfall, that the needle, instead of pointing to the N. star, varied but half a point, or between five and six degrees to the N.W., and still more on the following morning. Struck with this circumstance, he observed it attentively for three days, and found that the variation increased as he advanced. He at first made no mention of this phenomenon, knowing how ready his people were to take alarm; but it soon attracted the attention of the pilots, and filled them with consternation. It seemed as if the laws of nature were changing as they advanced, and that they were entering another world, subject to unknown influences. They apprehended that the compass was about to lose its mysterious virtues; and, without this guide, what was to become of them in a vast and trackless ocean? Columbus tasked his science and ingenuity for reasons with which to allay their terrors. He told them that the direction of the needle was not to the polar star, but to some fixed and invisible point. The variation was not caused by any failing in the compass, which, like the other heavenly bodies, had its changes and revolutions, and every day described a circle round the pole. The high opinion that the pilots entertained of Columbus as a profound astronomer gave weight to his theory, and their alarm subsided."[1] Although the details which we have already given afford sufficient proof that the variation of the needle had been discovered two hundred years before the time of Columbus, yet it is evident, from the above passage, that he had discovered the variation of the variation, or that the variation was not a constant quantity, but varied in different latitudes.

Change in the variation.

Norman.

Burough.

Notwithstanding these casual observations on the variation of the compass, no accurate measures of its amount were made till about the middle of the sixteenth century. In 1541 it was found that the declination of the needle from the meridian of Paris was about 7° or 8° easterly. In 1550 it was 8° or 9°, and in 1580, 11½° easterly. Norman,[2] who first observed the variation in London, made it 11° 15′ easterly; and Mr Burough,[3] comptroller of the navy, in 1580 found it to be at an average 11° 19′ E. at Limehouse. The following observations made at other places will show the gradual change in the variation:—

Burough	1580	11°	19′	E. Limehouse.
Gunter	1612	5	36	E. London.
Gellibrand[4]	1633	4	4	E. London.
Petit	1630	4	30	E. Paris.
Petit	1660	0	10	E. Paris.
Auzout	1670	2	0	W. Rome.
Hevelius	1642	3	5	W. Dantzig.
Hevelius	1670	7	20	W. Dantzig.

Dip of the needle discovered by Norman, A.D. 1576.

The important discovery of the *dip* or inclination of the needle was made in 1576, by Robert Norman, whom we have already mentioned. Having constructed many compasses, and having always balanced the needles for them before he touched them with the magnet, he invariably found, that after they were touched the north point always inclined below the horizon, so that he was obliged to make the card of the compass level by putting some small pieces of wire on the end of it. Having mentioned this discovery to some of his friends, he was advised to construct an instrument which would enable him to measure the greatest angle which it would make with the horizon. With this instrument, which is the dipping needle in its first and rudest form, he found the dip to be at 71° 50′; an observation which, according to Bond, must have been made about 1576.

J. Cæsar.

That ferruginous substances always possess a greater or a less degree of magnetism, has been long known. One Julius Cæsar, a surgeon of Rimini, first observed the conversion of iron into a magnet. In 1590 he noticed this effect on a bar of iron which had supported a piece of brick-

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[1] Washington Irving's *Life and Voyages of Columbus*, vol. i., p. 201.

[2] *The New Attractive*, by Robert Norman, Lond. 1596.

[3] *A Discourse on the Variation of the Compass*, Lond. 1581.

[4] *Discourse Mathematical on the Variation of the Magnetical Needle*, 1635. Gellibrand found that the N.E. of the needle was gradually moving to the westward.

Gassendi.

work on the top of a tower of the church of St Augustin. The very same fact was observed about 1630 by Gassendi, on the cross of the church of St John at Aix, which had fallen down in consequence of having been struck with lightning. He found the foot of it wasted with rust, and possessing all the properties of a loadstone.

Dr Gilbert. A.D. 1600.

While magnetism was making slow advances by means of insulated observations, it was destined to receive a vigorous impulse from the pen of Dr Gilbert of Colchester. This eminent individual, who was physician in ordinary to Queen Elizabeth, published, in 1600, his *Physiologia Nova, seu Tractatus de Magnete et Corporibus Magneticis*, a work which contains almost all the information concerning magnetism which was known during the two following centuries. It relates chiefly to the natural loadstone, and to artificial magnets, or bars of steel which have acquired similar properties. He applies the term magnetic to all bodies which are acted upon by loadstones and magnets, in the same manner as they act upon each other, and he finds that all such bodies contain iron in some state or other. He considers the phenomena of electricity as having a considerable resemblance to those of magnetism, though he points out the differences by which the two classes of phenomena are marked. In treating of the directive power of the needle, he supposed, "that the earth itself being in all its parts magnetical, and the water not, wherever the land was, there would the needle turn, as to the greater quantity of magnetical matter." He regarded the earth as acting upon a magnetized bar, and upon iron, like a magnet, the directive power of the needle being produced by the action of magnetism of a contrary kind to that which exists at the extremity of the needle directed towards the pole of the globe. He gave the name of *pole* to the extremities of the needle which pointed towards the poles of the earth, conformably to his views of terrestrial magnetism, calling the extremity that pointed towards the N. the *south pole* of the needle, and that which pointed to the S. the *north pole*.

Bond. A.D. 1650.

About the year 1650, Mr Bond, a teacher of mathematics in London, who had been employed to superintend the publication of the popular treatises on navigation, published a work called the *Seaman's Calendar*, in which he maintains that he has discovered the true progress of the deviation of the compass; and in another book, called *The Longitude Found*, and in the *Phil. Trans.* 1668, he published a table of the computed variations for London for many years to come, extending from 1663 to 1716. The results which this table contains agree very nearly with those which were observed for the next twenty-five years, but after that the differences became very great. In a subsequent paper in the *Phil. Trans.* for 1673, Bond attempted to account for the change in the variation and dip of the needle, by *two magnetic poles*, and a magnetic axis inclined to the axis of the earth. He asserted that he knew the period of this revolution, as well as its cause; and he proposed to determine the longitude by means of the dip of the needle. He did not, however, think proper to communicate either his views or method to the public.

Newton, &c.

Newton, Huygens, Hooke, and some of the other philosophers who flourished about the end of the seventeenth century, were occupied, though not to a great degree, with the subject of magnetism. Some of their observations and discoveries are referred to in a manuscript volume of notes and commentaries, written by David Gregory in 1693, in a copy of Newton's *Principia*, and used by Newton in improving the second edition. Newton, who considered the magnetic force as different from that of gravity,[1] had supposed that the law of magnetic action approaches to the inverse triplicate ratio of the distance; but Gregory did not adopt this opinion, and invalidates the arguments which were used in its support. Newton committed another mistake in asserting, as we shall afterwards see, that red hot iron has no magnetic property.

Dr Hooke, A.D. 1684.

Several interesting experiments had been made by Dr Gilbert, on the effects of heat in destroying magnetism, and also in inducing it in substances susceptible of being impregnated. He likewise made numerous experiments with bars of iron and steel placed in the magnetic meridian and exposed to great heats. Dr Hooke took up this subject in 1684. He used rods of iron and steel about seven inches long and one-fifth of an inch in diameter, and he found that they acquired permanent magnetism when strongly heated in the magnetic meridian, and allowed to cool in the same position. The permanency of the effect was greater, and the magnetism stronger, when the rods were suddenly cooled in cold water, so as to give them a very hard temper. He found that the end which was next to the N., or the lower end of a vertical bar, was invariably a permanent N. pole. Even when the upper end alone was quenched, while the rest of the bar cooled slowly, that end became a sensible S. pole. If the same process was adopted when the steel bar lay at right angles to the magnetic meridian, no magnetism was acquired.

Dr Halley. A.D. 1672, 1683.

The subject of terrestrial magnetism now occupied the attention of our eminent countryman, Dr Edmund Halley. He had observed a change in the variation of the needle so early as 1672, a year before he left school; and in 1683, he published[2] his *Theory of Magnetism*, which to a certain extent forms the nucleus of more modern hypotheses. He regarded the earth's magnetism as caused by four poles of attraction, two of them near each pole of the earth; and he supposes "that in those parts of the world which lie nearly adjacent to any one of these magnetic poles, the needle is governed thereby, the nearest pole being always predominant over that more remote." He supposes that the magnetic pole, which was in his time nearest Britain, was situated near the meridian of the Land's End, and not above 7° from the N. pole; the other N. magnetic pole, the strongest, being in the meridian of California, E. Long. 246°, and about 15° from the N. pole of the earth. He placed one of the two S. poles about 16° from the S. pole of the globe, and 95° W. from London; and the other, or the most powerful of the four, about 20° from the S. pole, and 120° E. of London.

Dr Halley's theory.

In order to account for the change in the variation, Dr Halley, some years afterwards, added to these reasonable suppositions the very extraordinary one, that our globe was a hollow shell, and that within it a solid globe revolved, in nearly the same time as the outer one, and about the same centre of gravity, and with a fluid medium between them. To this inner globe he assigned two magnetic poles, and to the outer one other two; and he conceived the change in the variation of the needle to be caused by a want of coincidence in the times of rotation of the inner globe and the external shell. "Now, supposing," says he, "such an external sphere having such a motion, we may solve the two great difficulties in every former hypothesis; for if this exterior shell of earth be a magnet, having its poles at a distance from the poles of diurnal rotation; and if the internal nucleus be likewise a magnet, having its poles in two other places, distant also from its axis, and these latter, by a gradual and slow motion, change their places in respect of the external; we may then give a reasonable account of the four magnetic poles, as also of the changes of the needle's variation." From some reasons which Dr Halley then states, he concludes "that the two poles of the external globe are fixed in the earth, and that if the needle were wholly governed by them, the variation would be always the same, with some little irregularities; but the internal sphere, having such a gradual translation of its poles, influences the needle, and directs it variously, according to the result of the attractive and directive power of each pole, and consequently there must be a period of revolution of this internal ball, after which the variation will return as before."

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[1] *Principia*, lib. iii., prop. 6.

[2] *Phil. Trans.*, No. 248.

This theory excited so much notice, that an application was made to William and Mary, for a ship, "in order to seek, by observation, the discovery of the rule for the variation of the compass." The command of a ship of the royal navy was in consequence given to Dr Halley; and, in the accomplishment of the object which he had in view, he performed two voyages, one in 1698 and the other in 1699, in which he traversed various parts of the Pacific and Atlantic Oceans, and obtained such a number of valuable results, that he completed and published in 1701 a chart of the variation of the needle, which exhibited to the eye the general law of its phenomena, by means of lines joining those places where the variation was equal.

Graham. A.D. 1722.

Daily variation discovered.

The very important discovery of the daily variation of the needle was made in 1722, by Mr Graham, a celebrated mathematical instrument maker in London. While the needle was advancing by an annual motion to the westward, Mr Graham found that its N. extremity moved westward during the early part of the day, and returned again in the evening to the eastward, to the same position which it occupied in the morning, remaining nearly stationary during the night. Mr Graham at first ascribed these changes to defects in the form of his needles; but, by numerous and careful observations, repeated under every variation of the weather and of the heat and pressure of the atmosphere, he concluded that the daily variation was a regular phenomenon, of which he could not find the cause. It was generally a maximum between ten o'clock A.M. and four o'clock P.M., and a minimum between 6 and 7 o'clock P.M. Between the 6th February and the 12th May 1722, he made a thousand observations in the same place, from which he found that the greatest westerly variation was 14° 45′ and the least 13° 50′; but in general it varied between 14° 35′ and 14°, giving 35′ for the amount of the daily variation.

Law of the magnetic force.

Whiston, Hauksbee, and Brooke Taylor.

The law of the magnetic force, or the rate at which it varies with the distance, had, as we have seen, occupied the attention of Sir Isaac Newton and David Gregory. Numerous experiments were made by various authors for the same purpose, a large collection of which have been published by Scarella, in his treatise *De Magnete*, published at Brescia in 1759. Muschenbroeck[1] made a great number of experiments with the same view; but as the joint action of the four poles was never considered, the precise law of variation remained unknown. Mr Whiston, Mr Hauksbee, and Dr Brooke Taylor employed a much better method, namely, the deviation of a compass-needle from the meridian, produced by the action of a magnet at different distances; and the conclusion which they drew from their experiments was, that the magnetic force was proportional to the sines of half the arcs of deviation, or nearly in the inverse sesqui-duplicate ratio of the distance, or as the square roots of the fifth powers of the distances.[2]

Mr Michell.

Notwithstanding this strange conclusion, the observations to which we have referred were of great value; and Mr Michell[3] succeeded in deducing from them, in 1750, the true law of magnetic action. "There have been," says Mr Michell, "some who have imagined that the decrease of the magnetic attraction and repulsion is inversely as the cubes of the distances; others, as the squares; and others, that it follows no certain ratio at all, but that it is much quicker at great distances than at small ones, and that it is different in different stones. Among the last is Dr Brooke Taylor and Muschenbroeck, who seem to have been pretty accurate in their experiments. The conclusions of these gentlemen were drawn from their experiments, without their being aware of the third property of magnets just mentioned, which, if they had made proper allowances for, together with the increase and diminution of power in the magnets they tried their experiments with, all the irregularities they complained of (as far as appears from their relations of them) might very well be accounted for, *and the whole of their experiments coincide* with the squares of the distances inversely."

Torsion balance.

It is to Mr Michell also that we owe the introduction of the torsion balance, for measuring small forces; an instrument which, as we shall see, was employed with singular success and dexterity by Coulomb in his electrical, magnetical, and hydrodynamical researches: and the science of magnetism is no less indebted to Mr Michell for his invention of the method of double touch, as it is called, by which artificial magnets may be made with greater strength than could have been obtained from the previous method of Duhamel. Dr Gowen Knight, who first taught us to make powerful magnets, accounted for the phenomena of magnetism by supposing that a fluid whose particles repelled each other exists in space and in the pores of steel, and passes in one direction only between magnetic poles. Attraction takes place when the fluid circulates from the S. pole of one magnet to the N. pole of another, and repulsion from its circulation from the N. or S. pole of one magnet to the same pole of the other.[4]

Descartes.

Euler. A.D. 1757.

The hypothesis of Descartes, who explained the polarity of the needle by means of currents moving rapidly from the equator to the poles, was adopted and defended by Euler and Daniel Bernoulli; but we cannot afford any space for such useless speculations. Euler afterwards occupied himself more advantageously for science in attempting to investigate mathematically the direction of the needle on every part of the earth's surface.[5] Perceiving the intricacy which would arise from the adoption of four poles, as imagined by Halley, he tried the effect of employing two poles not diametrically opposite; and he found, that when a proper position was given them, the variation under the same meridian might be both easterly and westerly, as in Halley's chart. The solution which he has given is founded on the principle, "that the magnetic direction on the earth follows always the small circle which passes through the given place, and the two magnetic poles of the earth;" or that the horizontal needle is a tangent to the circle passing through the place of observation, and through the two points on the earth's surface where the dipping needle becomes vertical, or the horizontal needle loses its directive power. In the application of this principle, Euler makes four different suppositions respecting the magnetic poles: 1. That they are diametrically opposite to each other; 2. That they are in opposite meridians, but not in opposite parallels; 3. That they are on the same meridian; and, 4. That they have every other situation whatever. The first of these suppositions he finds to be quite irreconcileable with the observed phenomena, but in the other three he finds that the variation may be both easterly and westerly in the same meridian. By successive approximations he finds the position of the two magnetic poles in 1757 to be as follows:—The N. pole in Lat. 76. N., and Long. 96. W. from Tene-

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[1] Muschenbroeck's experiments, though valuable in themselves, led to no definite results. They will be found in *Phil. Trans.*, 1725; *Introduction to Natural Philosophy*, 1744; and *Essai de Physique*, 1751.

[2] *Phil. Trans.*, Nos. 368, 396. Dr Brooke Taylor had, in an earlier paper (*Phil. Trans.*, 1721) come to the conclusion that the force was different in different magnets, and decreased quicker at great distances than at small ones, an experimental fact, as shown by Sir W. Harris, *Rudimentary Magnetism*, part iii., 224.

[3] *A Treatise of Artificial Magnets*, 8vo, Lond. 1750, p. 19.

[4] *Attempt to Explain the Phenomena of Nature*, Lond. 1748.

[5] *Berlin Memoirs*, 1757, 1766.

History.

riffe; and the S. pole in Lat. 58. S., and Long. 158. W. from Teneriffe. To this dissertation Euler has added a chart of the curves of equal variation, calculated on the preceding principles, and suited to 1757; and their general accordance with observation is very surprising. In a subsequent dissertation Euler endeavoured to improve his theory, by supposing the two magnetic poles to be at the surface of the earth. The chord joining these poles he calls the magnetic axis, and the middle point of that chord its magnetic centre. Then, if we draw a line from the place of observation to the magnetic centre, and consider this as the base of an isosceles triangle, one of whose sides is the magnetic axis, the other side will be the direction of a freely suspended needle. This hypothesis, though it has various defects, fulfils, as has been remarked, certain conditions that are essential to a good theory. 1. It gives the needle the approximately accurate positions at the equator, the needle and the axis being then parallel. 2. It fulfils the condition of the needle and axis, forming a continuous line at the poles. 3. It furnishes two points at which the needle would be vertical; and 4. It gives a series of positions, single for each place, and having a certain, and oftentimes pretty close, approach to the true position.

A.D. 1766.

Tobias Mayer.

The celebrated Tobias Mayer, in an unpublished memoir, read before the Royal Society of Göttingen, gave an account of a series of experiments on magnetism, from which he concluded that the force was in the inverse ratio of the square of the distance. Experiments made about the same time by Benjamin Martin,[1] indicate a force inversely as the square roots of the cubes of the distances.

Lambert. A.D. 1756.

The law of magnetic action occupied the particular attention of M. Lambert, the celebrated Prussian philosopher, who has published an account of his labours in the *Memoirs of the Academy of Berlin* for 1756. Having placed a mariner's compass at various distances from a magnet, and in the direction of its axis, he observed the declination of the needle produced by the magnet, and the obliquity of the magnet to the needle's axis. From several observations at different obliquities, he found that the action of magnetism on a lever was proportional to the sine of the angle of its obliquity to the axis of the lever or needle. M. Lambert then proceeded to study the effect of distance, and he discovered that the force of a magnet is proportional to the distance of the nearest pole of the magnet from the centre of the needle, diminished by the square of a constant quantity, nearly equal to two-thirds of the length of the needle. This result he found to be true with magnets ten times larger, and needles twice as short; but as the law led him to a strange result, as if the action on a magnet were exerted from a centre beyond itself, he was therefore obliged to take another method of determining the law of action, namely, by a series of experiments on the directive power of the magnet,[2] from which he inferred, "that the force of each transverse element of a magnet is as its distance from the centre, and its action on a particle of another magnet inversely as the square of the distance." By means of this law he calculates the position of a very small needle, and draws three of the curves to which it should be a tangent, and these coincide very accurately with some of those which he had observed.[3]

Dr Robison. A.D. 1769.

Our countryman, Dr Robison, had been pursuing similar inquiries before he had seen Lambert's experiments. He got some magnets made, composed of two balls connected by a slender rod; and after magnetizing them strongly, he found that the force of each pole resided nearly in the centre of the ball. In this way the attractive and the directive powers of the magnets were easily computed; and the result was, that the force of each pole was inversely as the square of the distance. In no case did the error of this hypothesis amount to one-fifteenth of the whole; and in the calculation for the phenomena of the directive power, the errors were still smaller. When Dr Robison had seen Lambert's second memoir, he repeated all his former experiments in Lambert's manner, taking the precaution of keeping the needle in its natural position, which he had not previously attended to; and the results which he now obtained were still more conformable to his conjecture as to the law of variation. Dr Robison tried another method of ascertaining the law of magnetic action. In 1769, or 1770, he constructed a needle of two balls joined by a slender rod; and having touched it with great care, so as to keep the whole strength of the poles near the centre of the balls, he counted the number of oscillations which it performed horizontally in a given time by the force of the earth's magnetism. "He then placed it on the middle of a very fine and large magnet, placed with its poles in the magnetic meridian, the N. pole pointing S. In this situation he counted the vibrations made in a given time. He then raised it up above the centre of a large magnet, till the distance of its poles from those of the great magnet was changed in a certain proportion. In this situation its vibrations were again counted. It was tried in the same way in a third situation, considerably more remote from the great magnet. Then having made the proper reduction of the forces corresponding to the obliquity of their action, the force of the poles of the great magnet was computed from the number of vibrations." The results of these experiments were the most consistent with each other of any that Dr Robison made for determining the law of the magnetic force; and it was chiefly from them that he thought himself authorized to say, with some confidence, that it is inversely as the square of the distance. When Dr Robison, however, observed, some years afterwards, that Æpinus, in 1777, conceived the force to vary inversely as the simple distance, he repeated the experiments with great care, and added another set made with the same magnet, and the same needle placed at one side of the magnet instead of above it. By this arrangement, which greatly simplified the process, the result of the whole was still more satisfactory. The inverse law of the square of the distance was therefore well established.

Theory of Æpinus. A.D. 1759.

Various speculations respecting the cause of the phenomena of magnetism had been hazarded by different authors; but it was reserved for M. Æpinus to devise a rational hypothesis, which embraced and explained almost all the phenomena which had been observed by previous authors. This hypothesis, which he has explained at great length in his *Tentamen Theoriæ Electricitatis et Magnetismi*, published in 1759, may be stated in the following manner:—

1. In all magnetic bodies there exists a substance which may be called the magnetic fluid, whose particles repel each other with a force inversely as the distance.

2. The particles of this fluid attract the particles of iron, and are attracted by them in return with a similar force.

3. The particles of iron repel each other according to the same law.

4. The magnetic fluid moves through the pores of iron and soft steel with very little obstruction; but its motion is more and more obstructed as the steel increases in hardness or temper, and it moves with the greatest difficulty in hard-tempered steel and the ores of iron.

Methods of making artificial magnets.

The method of making artificial magnets, which was practised by the philosophers of the seventeenth century, was a very simple, but a very inefficacious one. It consisted in merely rubbing the steel bar to be magnetized upon one of the poles of a natural or artificial magnet, in a direction at right angles to the line joining the poles of the magnet. Towards the middle of the eighteenth century, however, the art of making artificial magnets had excited general attention.

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[1] *Philos. Britannica*, vol. i., p. 47.

[2] *Memoirs of the Berlin Academy*, vol. xxii.

[3] A popular account of Lambert's researches will be found in Sir William Snow Harris's *Rudimentary Magnetism*, part iii., arts. 191–203.

Marcel, Savery, and Desaguliers had succeeded in making tolerably good artificial magnets; but it is to Dr Gowin Knight, an English physician, that we are indebted for the discovery of the first good method of making powerful magnets. This method he kept secret from the public; but it was afterwards published by Dr Wilson. Duhamel, Canton, Michell, Antheaume, Savery, Æpinus, Robison, Coulomb, Biot, Scoresby, Logeman, and others, made various improvements on this art, which will be described when we arrive at that part of our subject.

Experiments of Canton.
A.D. 1756.

The science of magnetism owes many obligations to Mr John Canton, one of the most active experimental philosophers who adorned the middle of the eighteenth century. In or previous to the year 1756, he made no fewer than 4000 observations on the diurnal variation of the needle, with the view of determining its amount, and investigating its origin. He found the daily change different in different seasons of the year, as shown in the following table:—

January	7′ 8″	July	13′ 14″
February	8 58	August	12 19
March	11 17	September	11 43
April	12 26	October	10 36
May	13 0	November	8 9
June	13 21	December	6 58

He found, also, that the time of minimum westerly variation at London was between eight and nine o'clock A.M., and the time of maximum between one and two o'clock P.M., the needle returning to its morning position about eight or nine in the evening. A series of similar observations were made with nearly the same results by Mr Van Swinden; but this excellent observer discovered, that some time before the hour in the morning when the westerly minimum took place, and after the same hour in the evening, a motion of the needle both to the eastward and westward took place; that is, the morning westerly variation is sometimes preceded by a small easterly variation, and the principal easterly variation in the evening is followed by a small westerly variation.

Van Swinden.

Canton explained the westerly variation of the needle, and the subsequent easterly motion, by supposing that the heat of the sun, acting upon the eastern parts of the earth, weakens their influence, as heat is known to do that of a magnet, and consequently the needle will move to the westward. In the same way, as the sun warms the western side of the earth in the afternoon, the needle will then take a contrary direction.

Discoveries of Coulomb.

One of the ablest cultivators of the science of magnetism was the celebrated Coulomb, who, by the application of the principle of torsion, first used by Michell, determined the correct law of magnetic attractions and repulsions. After measuring with great nicety, by the torsion balance, the force requisite to make a magnetic bar, suspended horizontally, deviate any number of degrees from a given position, he was enabled to verify the discovery of Lambert already mentioned, that the effect of terrestrial magnetism is proportional to the sine of the angle which the magnetic meridian forms with the axis of the magnet upon which it acts. By making the homologous poles of two magnetized wires repel each other, he observed the force of torsion which was necessary to overcome certain quantities of their mutual repulsion, and, at the distances 12°, 17°, and 24°, he found that the repulsive forces were as the numbers 3312, 1692, and 864, deviating little from 3312, 1650, and 828, which they would have been had the repulsive force varied in the inverse ratio of the square of the distance. The excess of 42 and 36 in the experimental numbers was owing to the circumstance that it was not a particle, but a portion of each wire from which the repulsive force emanated; so that the force of the other particles being exerted less obliquely, and, therefore, being stronger at greater distances, ought to produce an excess such as that actually observed. A similar result was obtained when the contrary poles of the magnetized wires were made to attract each other; so that Coulomb concluded that the attractive and repulsive forces exercised by two magnetic particles are inversely as the square of their distances, a result which he confirmed by several other methods than that which we have noticed.

Distribution of magnetism.

Discoveries of Coulomb.

Provided with such a delicate instrument as the torsion balance, Coulomb was enabled to apply it with singular advantage to almost every branch of the science. His first object was to determine the law according to which magnetism is distributed in a magnetic bar. It was of course well known that the magnetism in the middle of the bar was imperceptible, and that it increased according to a regular law, and with great rapidity, towards each of its poles. By suspending a small proof needle with a silk fibre, and causing it to oscillate horizontally opposite different points of a magnetic bar placed vertically, Coulomb computed the part of the effect which was due to terrestrial magnetism, and the part which was due to the action of the bar; and in this way he obtained the following results, which show the extreme rapidity with which magnetism is increased towards the poles.

Distances from the North end of the Bar.	Intensity of the Magnetism at these Distances.
0 inches.	165
1 „	90
2 „	48
3 „	23
4·5 „	9
6 „	6

In examining the distribution of electricity in a circular plane, Coulomb found that the thickness of the electric stratum was almost constant from the centre to within a very small distance of the circumference, when it increased all on a sudden with great rapidity. He conceived that a similar distribution of magnetism took place in the transverse section of a magnetic bar; and, by a series of nice experiments with the torsion balance, he found this to be the case, and established the important fact, that the magnetic power resides on the surface of iron bodies, and is entirely independent of their mass.

Effects of temperature.

The effect of temperature on magnets was another subject to which Coulomb directed his powerful mind; but he did not live to give an account of his experiments, which were published after his death by his friend M. Biot. Coulomb found that the magnetism of a bar, magnetized to saturation, diminished greatly by raising its temperature from 12° of Reaumur to 680°; and that when a magnetic bar was tempered at 780°, 860°, and 950°, of Reaumur, the development of its magnetism was gradually increased, being more than double at 900° of what it was at 780°. He found also that the directive force of the bar reached its maximum when it was tempered at a bright cherry-red heat at 900°; and that at higher temperatures the force diminished. It is to Mr Barlow, however, as we shall presently see, that we are indebted for the complete investigation of the influence of temperature on the development of magnetism.

Method of making artificial magnets.

Coulomb made many valuable experiments on the best methods of making artificial magnets, and he subjected all the various processes that had been previously employed to the test of accurate measurement. His experiments on the best forms of magnetic needles are equally valuable; but the most interesting of his researches, and the last to which he devoted his great talents, were those which relate to the action of magnets upon all natural bodies. Hitherto iron, steel, nickel, and cobalt, had been regarded as the only

Universal magnetism.

magnetic bodies; but, in the year 1802, Coulomb announced to the Institute of France, that all bodies whatever are subject to the magnetic influence, even to such a degree as to be capable of accurate measurement. The substances employed by Coulomb were in the form of a cylinder or small bar, about one-third of an inch in length and one-thirtieth in thickness, and they were suspended by a single fibre of silk between the opposite poles of two powerful steel magnets, placed in the same straight line, and having their opposite poles at a distance exceeding by a quarter of an inch the length of the cylinders. The cylinders were then made to oscillate between the poles of the magnets, and were protected from all motions of the air by a glass receiver. The result of these experiments was, that whatever was the substance of the cylinders, they always arranged themselves in a line joining the poles of the magnets, and returned to that position whenever they were deflected from it. These experiments were made with cylinders of gold, silver, copper, lead, tin, glass, wood, chalk, bone, and every variety of substance, organic and inorganic. The only explanation which Coulomb could give of these phenomena was, either that all bodies whatever were susceptible of magnetism, or that they contained small portions of iron or other magnetic metals, which communicated to them the property of obeying the magnet. In order to investigate this subject, MM. Sage and Guyton prepared highly purified needles of the different metals, and M. Coulomb found that the momenta of the forces with which they were solicited by the magnets were as follows:—

Lead	0·00674
Tin	0·00591
Silver	0·00520
Gold	0·00406
Copper	0.00406

the momentum of torsion alone, for all the needles, being 0·00136, a little more than a fourth of the action which the magnets exert upon the needles.

In order to determine if these phenomena were owing to particles of iron disseminated through the bodies, Coulomb fabricated needles out of three different mixtures of white wax and iron filings, and he found that the forces exerted by magnets upon these needles were proportional to the absolute quantities of iron which they contain. Coulomb now tried a needle of silver, purified by cupellation, and another needle of silver alloyed with $\frac{1}{320}$th part of iron, and he found that the action of the magnet upon the former was 415 times less than upon the latter. Hence there will be 415 times less iron in the pure than in the impure silver; and since the latter contains $\frac{1}{320}$th part of its weight of iron, the first will contain $\frac{1}{415}$th of $\frac{1}{320}$th, or $\frac{1}{132,800}$th, or it will contain 132,799 parts of pure silver and one of iron, a quantity of alloy beyond the reach of chemical detection.

The Abbé Haüy, by a process which he calls Double Magnetism, endeavoured to make Coulomb's process more effectual. He deflected a delicately-suspended magnetic needle from the meridian, by a magnetic bar placed so as to make the needle stand E. and W. A very feeble magnetic force was then sufficient to make it turn on its centre of suspension. M. Becquerel having found that a needle of soft iron might be used in place of the magnetic one of Haüy, formed his needles of several oxides of iron, inclosed in a thin paper case, suspended in different positions at a given distance from the pole of a magnetic bar; and he found, what may be considered as the first observed fact in diamagnetism, that the paper-case needles made of an admixture of the second and third oxides of iron, instead of directing themselves to the pole of the magnet like the soft-iron needle, stood at right angles to the line of the poles. Upon repeating Coulomb's experiment with needles of white wood and gum lac, suspended very near the magnets, but above the line of the poles, he found that they took the same position as the paper-case needles.

Humboldt. A.D. 1798-1803.

Amongst the scientific travellers who contributed to our knowledge of terrestrial magnetism, Baron Alexander Humboldt was one of the most distinguished. Himself an accurate and scientific observer, and possessed of nice instruments and methods of observation, he made numerous accurate observations on the dip and variation of the needle in various parts of the earth, and particularly near the magnetic equator; and by means of these valuable data, M. Biot was enabled to throw much light on the subject of terrestrial magnetism. Hitherto the magnetic poles had been considered as either on or very near the surface of the earth; but as it had been found impossible to deduce the phenomena of the variation and dip of the needle, philosophers were led to consider the situation of these poles as indeterminate. M. Biot was the first to adopt this view of the subject; and, after numerous comparisons, he came to the conclusion, that the nearer these poles were placed to each other, the greater was the agreement between the computed and observed results; and by considering the two poles as indefinitely near each other in the centre of the earth, the computed and observed measures approximated as closely as could be expected. Hence it was inferred that the phenomena of terrestrial magnetism were not such as are produced by permanently magnetic bodies, but those rather that arise from simple iron or ferruginous masses, which are only temporarily magnetic. In this manner M. Biot was led to express the law of terrestrial magnetism in a complicated formula, which represented the observations with wonderful accuracy.

M. Biot.

Professor Krafft.

In the year 1809 Professor Krafft of St Petersburg undertook the very same inquiry, and after comparing the same observations which were used by Biot, with the respective situations of the places where they were obtained, he arrived at the following simple law:—"If we suppose a circle circumscribed about the earth, having the two extremities of the magnetic axis for its poles, and if we consider this circle as a magnetic equator, the tangent of the dip of the needle, in any magnetic latitude, will be equal to double the tangent of this latitude." Upon re-examining his former formula, M. Biot found that it was reducible to the above simple law, a coincidence which may be considered as giving it additional confirmation.

Professor Hansteen.

One of the most zealous and successful cultivators of magnetical science is Professor Hansteen of Christiania, who published, in 1817, an able work on the magnetism of the earth.[1] The Royal Society of Denmark proposed, in 1811, the prize question, "Is the supposition of one magnetical axis sufficient to account for the magnetical phenomena of the earth, or are two necessary?" Professor Hansteen's attention had been previously drawn to this subject by seeing a terrestrial globe, on which was drawn an elliptical line round the S. pole, and marked *Regio Polaris magnetica*, one of the foci being called *Regio fortior*, and the other *Regio debilior*. As this figure professed to be drawn by Wilcke, from the observations of Cooke and Furneaux, Hansteen was led to compare it with the facts; and the result of the comparison being favourable, be was induced to study the theory of Halley, which had previously appeared to him wild and extravagant. The result of his researches, however, was favourable to that part of Halley's theory which assumes the existence of four poles and two

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[1] *Untersuchungen über den Magnetismus der Erde*, 4to, Christiania, 1817. This work was first made known in England by Sir David Brewster, in two articles in the *Edin. Phil. Journal* for 1820, vol. iii., p. 138, and vol. iv., p. 114; and an account of his subsequent researches, drawn up by Hansteen himself, appeared in the *Edin. Journal of Science* for 1826, vol. v., p. 65.

Hansteen's researches.

magnetic axes. Hansteen's *Memoir*, which was crowned by the Danish Society, forms the groundwork of the larger volume which he published in 1817. In his fifth chapter, on the Mathematical Theory of the Magnet, he deduces the law of magnetic action from a series of experiments similar to those of Hauksbee and Lambert. Assuming that the attraction or repulsion between any two magnetic particles is directly as the intensity of the force, and inversely as some unknown power t of the mutual distance of these particles, and supposing that the magnetic intensity of any particle is proportional to some power r of its distance a from the centre of the magnet, he finds the following expression for the effect F, which a linear magnet would have upon a magnetic point situated anywhere upon the axis produced:—

$$F=\int\frac{x^r\,dx}{(a-x)^t}-\int\frac{x^r\,dx}{(a+x)^t};$$

x being the length of half the axis of the linear magnet, and F (multiplied by a constant quantity, depending on the degrees of magnetism which the point and line possess) representing the force. In conducting the experiments, Hansteen placed a very sensible compass upon a horizontal table, so that the needle pointed to 0°. From beneath the centre of this needle, and perpendicular to its direction, or to the magnetic meridian, he drew a straight line upon the table, and divided it into portions, so that *ten* of them were equal to the half axis a of the artificial magnet. This magnet was then placed on the line at different distances from the needle, and the deviation of the needle from the magnetic meridian which it produced was accurately observed for each distance. Upon comparing the results, and calculating them by the formula, upon the supposition that t was 1 or 3, the differences were very great; but by making $t=2$, the calculated and observed results agreed remarkably well, as the following table shows:—

Values of a, or Distances in half Axes of the Magnet.	Values of F, or increase of the Force.			
	Observed Values.	Calculated Values.		
		$t=2$ $r=1$	$t=2$ $r=2$	$t=2$ $r=3$
11	1·000	1·000	1·000	1·000
10	1·306	1·334	1·334	1·325
9	1·834	1·835	1·836	1·836
7	3·947	3·938	3·945	3·949
5	11·015	11·072	11·119	11·154
4	22·441	22·245	22·411	22·530

On the law of magnetic force.

From this remarkable coincidence between the observed and the computed results, Hansteen concludes that "*the attractive or repulsive force with which two magnetic particles affect each other, is always directly as their intensities, and inversely as the squares of their mutual distance.*" He shows that the undetermined value of r produces almost no effect at considerable distances; and he is inclined to think that $r=2$, or that *the absolute intensity of any magnetic particle, situated in the axis, is proportional to the square of its distance from the middle point of that axis.* Mr Hansteen has also demonstrated that *the distance from the middle of a magnet being the same, the force opposite the poles, or in the direction of the axis, is double of the force in the magnetic equator.* If a globe contains at its centre an infinitely small magnet, Hansteen shows that, *near the magnetic equator, the dip must increase twice as rapidly as the magnetic latitude, and, near the pole, half as rapidly;* and that *the increment of the dip must be equal to the alteration of the latitude of that part of the globe where the dip is* 54° 44′. Our author also states, that if the earth had only one magnetic axis, whose centre coincided with that of the earth, the lines of equal dip would coincide with those of equal intensity; but as this is far from being the case, his opinion that there are two magnetic axes becomes more probable.

Hansteen's researches.

On terrestrial magnetism.

The most valuable part, however, of Professor Hansteen's work is that which relates to the number, position, and revolution of the magnetic poles. Having collected all the observations of value that had been made on the variation of the needle, he proved that there were *four points* of convergence among the lines of variation, viz., a weaker and a stronger point in the vicinity of each pole of the globe. The strongest poles N., S., lie almost diametrically opposite to each other, and the same is true of the weaker poles *n*, *s*. These four poles he found to have a regular motion obliquely, the two northern ones N, *n*, from W. to E., and the two southern ones S, *s*, from E. to W.

Since the publication of his results, Professor Hansteen obtained access to the valuable series of magnetical observations made during the British voyage of discovery to the arctic regions; and, after a diligent comparison of them, he obtained new and more accurate determinations of the positions and periods of revolution of the four magnetic poles, which will be found in our chapter on *Terrestrial Magnetism.*

With the view of discovering the nature of the forces by which the phenomena of terrestrial magnetism are produced, Professor Hansteen resolved to ascertain, at different parts of the earth's surface, the *intensity* of its magnetism, and to determine the form of the lines of equal intensity, or, as he calls them, the *isodynamical magnetic lines.* By means of the same needle intrusted to different philosophers, he had observations on the number of its oscillations in a given time made in every part of Europe; and he afterwards undertook a journey to Siberia to make the observations himself in that interesting magnetical region. From these observations he deduced the law given in our chapter on *Terrestrial Magnetism,* according to which the magnetic intensity varies with the dip of the needle.

Professor Hansteen's journey to Siberia was attended with secondary consequences of great value to science. The attention of the Russian government, and the Academy of Sciences at St Petersburg, was thus called to the subject of magnetism; and, on the recommendation of Baron Humboldt, the emperor liberally agreed to erect magnetic observatories in suitable stations, for determining, every *ten* years, the exact position of the *two lines of the variation,* which pass through his empire.

Diurnal changes.

In determining the intensity of terrestrial magnetism, Professor Hansteen observed that the time of vibration of a horizontal needle varied during the day. Graham had previously suspected a change of this kind, but his methods were not accurate enough to prove it. Hansteen, however, found that the *minimum* intensity took place between ten and eleven A.M., and the *maximum* between four and five P.M. He concluded also that there was an annual variation, the intensity being considerably greater in winter near the perihelion, and in summer near the aphelion; that the greatest *monthly* variation was a maximum when the earth is in its perihelion or aphelion, and a minimum near the equinoxes; and that the greatest daily variation is least in winter and greatest in summer. He found also that the aurora borealis weakened the magnetic force, and that the magnetic intensity is always weakest when the moon crosses the equator.

Influence of height.

In making experiments in the round tower at Copenhagen, Hansteen found that the magnetic intensity increased regularly towards the top, where it was a maximum;[1] and having extended his observations, he obtained the general result, that at the foot of any vertical object the needle oscillates *quicker* at the *north* side of it, and *slower* at the *south* side; whereas at the upper end it oscillates *quicker* at the *south* side, and *slower* at the *north* side. In the aerostatic ascent of MM. Gay-Lussac and Biot, they were unable to detect any change in the intensity of terrestrial magnetism at the height of 4000 metres. Saussure, however, had found that the intensity was considerably less on the Col du Géant than at Chamouni and Geneva, the difference in the levels of these places being, in the one case, 10,000, and in the other, 7800 feet, but his observations contradict his conclusion. M. Kupffer more recently obtained a similar result by observations on Mount Elburz, having found a decrease of intensity in rising 4500 feet above his first station; and he explains the result obtained by MM. Gay-Lussac and Biot, by supposing that an increase of intensity was produced by the diminution of temperature. Mr Henwood, on the other hand, made observations at the surface of Dolcoath mine, at 1320 feet beneath its surface, and on a hill 710 feet above the level of the sea, without being able to detect any difference in the intensity.

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[1] The height of the tower is 126 feet.

To the late Captain Foster[1] we owe many valuable observations on the magnetic intensity made at Spitzbergen and elsewhere. From these he concluded, that the diurnal change in the horizontal intensity is principally, if not wholly, owing to a small change in the amount of the dip. The maximum took place at about 3h 30m A.M., and the minimum at 2h 47m P.M., its greatest change amounting to one eighty-third of its mean value. Captain Foster is of opinion that these changes have the sun for their primary agent, and that his action is such as to produce a constant inflexion of the pole towards the sun during the 24 hours, an idea which Mr Christie had previously stated.[2]

Mr Barlow's discoveries.

About the year 1817, Professor Barlow of Woolwich turned his attention to the subject of magnetism, with the view principally of calculating the effect of a ship's guns on the compass. In trying the effects of different iron balls, he was led to the curious facts, that there exists round every globe and mass of iron a great circle inclined to the horizon at an angle equal to the complement of the dip of the needle; that the plane of this circle is a plane of no attraction upon a needle whose centre is in that plane; that if we regard this circle as the magnetic equator, the tangent of the deviation of the needle from its N. or S. pole will be proportional to the rectangle of the sine of the double latitude, and cosine of the longitude; that when the distance of the needle is variable, the tangent of deviation will be reciprocally proportional to the cube of the distance; and that, all things else being the same, the tangents of deviation will be proportional to the cubes of the diameters of the balls or shells, whatever be their masses, provided their thickness exceed a certain quantity.

These results were published in the first edition of Mr Barlow's *Essay on Magnetic Attractions;* but in the second edition of that work, he has published some curious results respecting the relative magnetic power of different descriptions of iron and steel, and on the effect of temperature on the quality and quantity of the attractive power of iron. The results of the first of these series of experiments were as follow, the numbers expressing the proportional magnetic power of the different descriptions of iron and steel:—

Malleable iron	100	Shear steel, hard	53
Blistered steel, soft	67	Cast iron	48
Blistered steel, hard	53	Cast steel, soft	74
Shear steel, soft	66	Cast steel, hard	49

In his experiments on the effects of temperature, Mr Barlow found that every kind of iron and steel possessed a greater capacity for the development of its magnetism when softened by heat than when cold; from which he concludes that its complete development when cold is prevented only by the hardness or resisting power of the metal. At a *white* heat he found that iron lost entirely its magnetic power, a result apparently inconsistent with the preceding conclusion; but, what was a still more extraordinary circumstance, when the *white* heat, at which there was no magnetism, began to subside into a *bright red*, or *red* heat, an *attractive* power showed itself the *reverse* of what it had when cold; and after it had passed through these two shades of colour, it resumed the same attractive power which it had when cold, the passage from the negative attraction of red passing into the positive attraction of the cold metal at the point of a red heat, the maximum, however, taking place at a blood-red heat.

Mr C. Bonnycastle.

The experimental laws of attraction of an iron shell or sphere, obtained by Mr Barlow, were first examined theoretically by Mr Charles Bonnycastle, who deduced them mathematically from the theory of Æpinus, which supposes the two magnetic fluids to be accumulated in the poles of magnets. This theory, however, led to some improbable consequences, and therefore Mr Barlow was induced to adopt that of Coulomb, with the modification, *that the magnetic power all resides on the surface of iron bodies; and is independent of the mass;* a modification which enabled Mr Barlow to obtain a general analytical expression of the disturbing power of an iron ball at its surface, as compared with that of the earth, and from which he deduced theoretically all his experimental laws.

Barlow's correcting plate.

These important discoveries enabled Mr Barlow to invent a most ingenious method of correcting the error of the compass, arising from the attraction of all the iron on board ships. This source of error had been noticed by Mr Wales, by Mr Downie in 1794, and by Captain Flinders; but it is to Mr Bain[3] that we owe the distinct establishment and explanation of this source of error. As a hollow shell of iron about four pounds in weight acts as powerfully at the same distance as a solid iron ball of 200 pounds weight, Mr Barlow happily conceived that a plate of five or six pounds weight might be made to represent and counteract the amount of the attraction of all the iron on board a vessel, and therefore leave the needle as free to obey the action of terrestrial magnetism as if there were no iron in the ship at all. After this ingenious contrivance had been submitted to the Admiralty, it was tried in every part of the world; and even in the regions which surround the magnetic pole, where the compass becomes useless, it never failed to indicate the true magnetic direction when the correcting plate was properly applied. At Port Bowen, where the dip is 88°, and the magnetic intensity which acts upon a horizontal needle extremely weak, the azimuth compass on board Captain Parry's ship gave the very same variation as that observed on shore. "Such an invention as this," says Captain Parry, "so sound in principle, so easy of application, and so universally beneficial in practice, needs no testimony of mine to establish its merits; but when I consider the many anxious days and sleepless nights which the uselessness of the compass in these seas had formerly occasioned me, I really should have esteemed it a kind of personal ingratitude to Mr Barlow, as well as great injustice to so memorable a discovery, not to have stated my opinion of its merits, under circumstances so well calculated to put them to a satisfactory trial." For this beautiful invention, the Board of Longitude conferred upon Mr Barlow the highest reward of L.500; and the Emperor of Russia, who was never inattentive to the interests of science, sent him a fine gold watch and a rich dress chain.

Magnetism of rotation.

A series of beautiful discoveries was made about this

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[1] *Phil. Trans.* 1828.

[2] *Phil. Trans.* 1827, pp. 345-349.

[3] *Treatise on the Variation of the Compass.*

Mr Christie.

time by M. Arago, Mr Christie, and Mr Barlow, on the influence of rotation on bodies both magnetic and non-magnetic. Mr Barlow, so early as 1818 or 1819, had found, that when a plate of iron was made to turn upon its centre, different parts of its circumference had different degrees of magnetic action on the compass; but here there was no effect discovered as due to rotation. In 1821, Mr Christie, in a series of experiments on iron plates, not only found that different parts in the circumference of the same plate had different attractive powers; but *that the same part had a different influence according as the same plate was made to revolve to the right or left hand.* Mr Christie therefore discovered that there was a *deviation due to rotation*, and that magnetical effects were produced which were nearly independent of the velocity of rotation, and which continued after the rotation had ceased. When the rotation was very rapid, the forces exerted upon the needle were always in the same direction as the forces derived from the slowest rotation, and which continue to act after the rotation has ceased, the former being to the latter nearly as three to two. From all the observations made by Mr Christie, he considers that the direction of the magnetic polarity acquired by rotation, whether at right angles to the line of the dip or not, has always a reference to the direction of the terrestrial magnetic force; and he infers that this magnetism is communicated to it from the earth. "It does not therefore appear from this," says Mr Christie, "that a body can become polarized by rotation alone, independently of the action of another body; so that, if from these experiments we might be led to attribute the magnetic polarity of the earth to its rotation, we must at the same time suppose a source from which magnetic influence is derived. Is it not, then, possible that the sun may be the centre of such influence, as well as the source of light and heat, and that, by their rotation, the earth and other planets may receive polarity from it?" When these experiments were repeated at Port Bowen, in 1825, by Captain Foster, the phenomena were exhibited on a more striking scale.

Mr Barlow.

In December 1824 Mr Barlow began a series of experiments, with the view of ascertaining whether magnetism, as produced by various processes with iron, could be excited or disturbed by rapid rotation. They were completed in January, but their publication was delayed till June, that an account of them might appear along with those of Mr Christie above mentioned. Mr Barlow's first experiments were made on a 13-inch shell attached to a lathe turned by a steam-engine, the mean speed of which was about 640 revolutions in a minute. The deviation of a needle exposed to its action increased with the velocity, and remained constant while the velocity continued constant, the needle always returning exactly to its original position the moment the motion of the ball ceased. This, therefore, is a phenomenon different from that observed by Mr Christie; a temporary effect wholly dependent on the velocity of rotation, whereas that observed by Mr Christie was permanent, and nearly independent of the number of revolutions. In examining the direction of the new force impressed upon the iron shell, he found it to be in every case equivalent to a polarization at right angles to the axis of rotation.

Discoveries of M. Arago.

Previous to the publication of these experiments, and without any knowledge of them, M. Arago had made the remarkable discovery, that if plates of copper and other substances are put into rapid rotation beneath a magnetized horizontal needle freely suspended, the rotatory plate will first cause the needle to deviate from its true direction; and by increasing the velocity, the deviation will increase, till the needle passes the opposite point, when it will continue to revolve, and at last with such velocity that the eye is unable to distinguish it.

M. Arago was led to this beautiful discovery by a previous series of experiments of great interest. He found that a magnetic needle oscillating above or near any body whatever, such as a plate of metal or a surface of water, gradually oscillated in arcs of less and less amplitude, as if it had been placed in a resisting medium; and, what was particularly remarkable, the number of oscillations performed in a given time was not changed. This curious fact was announced to the Academy of Sciences in Paris on the 22d of November 1824; and he was hence conducted to the still more remarkable discovery of the effects of rotation which we have already mentioned.

M. Seebeck.

M. Seebeck of Berlin repeated the experiments of M. Arago on the influence of plates of metal and other substances in diminishing the amplitude of oscillation; but we must reserve our account of them till we come to the chapter on that subject.

Mr Babbage and Sir John Herschel.

The experiments of M. Arago on the rotation of metallic plates were described and repeated by M. Gay-Lussac in London, in the month of March or April 1825; and they excited so much attention, from their connection with the effects observed by Mr Barlow, that Mr Babbage and Sir John Herschel immediately erected an apparatus for repeating them. In their first trial, the deviation of the needle did not exceed 10° or 11° with a revolving plate of copper. In order to enlarge the visible effect, they reversed the experiment, in order to try whether discs of copper and other non-magnetic substances might not be set in motion if suspended over a revolving magnet. A horse-shoe magnet, capable of lifting twenty pounds, was made to revolve rapidly about its axis of symmetry placed vertically. A circular disc of copper, six inches in diameter and one twenty-fifth of an inch thick, was suspended centrally over it, by a silk thread just capable of supporting it. A sheet of paper being interposed and the magnet set in motion, the copper began revolving in the same direction, at first slowly, but with an accelerating velocity. On reversing the motion of the magnet, the velocity of the copper was destroyed gradually. It stopped for an instant, and then immediately began to revolve in the opposite direction. Screens of paper, glass, wood, copper, tin, zinc, lead, bismuth, were interposed betwixt the magnet and the copper but they exerted no sensible interceptive power. But when tinned iron plate was interposed, the magnetic influence was greatly diminished by one plate, and almost annihilated by two thicknesses of it. A piece of iron connecting the two poles of the revolving magnet produced the same effect. The substances in which signs of magnetism were developed by the revolving magnet were—copper, zinc, silver, tin, lead, antimony, mercury, gold, bismuth, and carbon in the state in which it is precipitated from carburetted hydrogen in gas-works. By getting plates of different metals cast in the same mould, they found that the proportional intensity of magnetic action for each respectively was as follows:—

Zinc	1·11	Lead	0·25
Copper	1·00	Antimony	0·01
Tin	0.51	Bismuth	inappreciable.

M. Arago had observed the very remarkable fact, that if the disc of copper be cut from the circumference towards the centre, like radii, but without taking away the metal, the action upon the needle is greatly diminished. After verifying this result, Messrs Babbage and Herschel ascertained that re-establishing the metallic contact with other metals, restored, either wholly or very nearly, the original power of the plate, even though the soldering metal had a very feeble magnetic power. The law of the force, with a decrease of distance, they found to vary between the square and the cube. "The rationale," they say, "of these phenomena, as well as of those observed by Mr Barlow in the rotation of iron, which form only a particular case (though

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certainly the most prominent of any) of the class in question, seems to depend on a principle which, whether it has or has not been before entertained, or distinctly stated in words, it may be as well, once for all, to assume here, as a *postulatum*, viz., that *in the induction of magnetism, time enters as an essential element, and that no finite degree of magnetic polarity can be communicated to or taken from any body whatever, susceptible of magnetism, in an instant.*"

The preceding results were verified by Mr Christie, who found, that when a thick plate of copper revolved under a small magnet, the force which deflected the needle varied inversely as the fourth power of the distance; but when the copper discs were small, and the magnets large, the power of the distance was between the square and the cube; when the plates were of different weights, the force was nearly in the ratio of the weights at small distances, but at smaller distances it varied in a higher ratio.

Connection between the magnetic poles and those of maximum cold.

The discovery of two poles of maximum cold on opposite sides of the N. pole of the earth, which was announced by Sir David Brewster in 1820, led him and other authors to the opinion that there might be some connection between the magnetic poles and those of maximum cold. "Imperfect," says he, "as the analogy is between the isothermal and magnetic centres, it is yet too important to be passed over without notice. Their local coincidence is sufficiently remarkable, and it would be to overstep the limits of philosophical caution to maintain that they have no other connection but that of accidental locality; and if we had as many measures of the mean temperature as we have of the variation of the needle, we might determine whether the isothermal poles were fixed or moveable." And he concludes his paper on the mean temperature of the globe with the following paragraph:—"Having thus endeavoured to establish a new law of the distribution of heat over the surface of the globe, it might be no uninteresting inquiry to investigate the causes which have modified in so remarkable a manner the influence of the solar rays. The subject, however, is too comprehensive and too hypothetical to be discussed at present. How far the general form and position of the continents and seas of the northern hemisphere may disturb the natural parallelism of the isothermal lines to the equator—to what extent the current through Behring's Strait, transporting the waters of warmer climates across the polar seas, may produce a warm meridian in the direction of its motion, and throw the coldest parts of the globe to a distance from the pole—whether or not the magnetic, or galvanic, or chemical poles of the globe (as the important discoveries of Oersted entitle us to call them), may have their operations accompanied with the production of cold, one of the most ordinary effects of chemical action—or whether the great metallic mass which crosses the globe, and on which its magnetic phenomena have been supposed to depend, may not occasion a greater radiation of heat in those points where it developes its magnetic influence—are a few points which we may attempt to discuss when the progress of science has accumulated a greater number of facts, and made us better acquainted with the superficial condition as well as the internal organization of the globe."[1]

The two poles of maximum cold, which will likely perform an important part in the future history of terrestrial magnetism, are situate, according to Sir David Brewster, as follows, according to the best observations made both near them and at a distance:—The American pole is situate in N. Lat. 73., and W. Long. 100. from Greenwich, a little to the E. of Cape Walker; and the Asiatic pole in N. Lat. 73., and E. Long. 80., between Siberia and Cape Matzol, on the Gulf of Oby. Hence, the two warm meridians will be in W. Long. 10., and E. Long. 170., the latter passing through Lord Mulgrave's range, and the former between St Helena and Ascension Island. The two cold meridians, or those which pass through the poles of maximum cold, will be in W. Long. 100., and E. Long. 80., the latter passing near Mexico and through Bathurst Island, and the former through Colombo in Ceylon, Berar in Hindustan, and crossing the Oby a little to the W. of Narym in Siberia. The following is the formula which the same author has given for the mean temperature at any point of the globe, T being the mean temperature required, t the maximum equatorial temperature, τ the minimum temperature at each of the cold poles, and δ, δ' the distances of the place from the two cold poles:—

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$$T=(t-\tau)\,(\sin.^n\delta\,.\,\sin.^n\delta')+\tau.$$

The distances δ, δ' are found from the formulæ—

$$\cos.\,\delta=\frac{\cos.\,L\,(\cos.\,L-\theta)}{\cos.\,\theta}\text{ and}$$

$$\text{tang. }\theta=\cos.\,M\text{ tang. }L\,;$$

in which L is the co-latitude of the pole of maximum cold, l the co-latitude of the place, and M the difference of longitude between the place and the pole of maximum cold. The values of t and τ have been determined with considerable accuracy, t being nearly 82°·8 Fahrenheit, and τ from 0° to $-3\frac{1}{2}$°. The exponent n is nearly $\frac{5}{8}$ths, but future observations may induce us to increase or diminish it.

Now, it is a remarkable circumstance that the same formula, *mutatis mutandis*, expresses the approximate magnetic intensity of magnetism at any point of the earth's surface, the intensity at the two magnetic poles being supposed equal. If we call S the maximum number of seconds in which any number n of oscillations are performed which takes place at the Island of St Thomas, on the W. coast of Africa, and s the minimum number of seconds in which n oscillations are performed, which takes place at the magnetic poles, then the intensity I will be

$$I=(S-s)\,(\sin.^n\delta\,\sin.^n\delta')+s,$$

δ and δ' being determined by the formulæ already given; adopting the position of the poles in the preceding page. The values of S and s, according to General Sabine and Hansteen, will be about 370″ and 262½″. This formula will give for the *isodynamical lines* a series of returning curves of the nature of Lemniscates, almost similar to those drawn by General Sabine, as given in a future figure, and exactly like the polar isothermal lines.

Connection between the temperature and magnetism of the globe.

The connection thus indicated between the heat and the magnetism of the earth has been studied by succeeding authors, and the general principle has been adopted by many distinguished philosophers. Dr Traill expressed the opinion, "that the disturbance of the equilibrium of the temperature of our planet by the continual action of the sun's rays on its intertropical regions, and by the polar ices, must convert the earth *into a vast thermo-magnetic apparatus*;" and "that the disturbance of the equilibrium of temperature, even in stony strata, may elicit some degree of magnetism." Mr Christie thinks it "not improbable that difference of temperature may be the primary cause of the polarity of the earth, though its influence may be modified by other circumstances." M. Ampère, who ascribes magnetism to transverse electrical currents, thinks that the strata of our globe may form considerable galvanic arrangements, and that the electric currents may be affected by the rotation of the earth. M. Oersted remarks, in his treatise on thermo-electricity,[2] "that the most efficacious excitation of electricity upon the earth appears to be produced by the sun producing daily evaporation, de-oxidation, and heat, all of which excite electrical currents." After stating that the sun daily produces electric currents, and these currents magnetism, he observes, that "thus the earth seems to have a *constant magnetic polarity*, produced in the course of time by the electrical currents which surround it, and a *variable magnetism* produced immediately by the same current." As the sun produces different effects on water and solid bodies, Oersted supposes that the intensity will vary in the same parallel, and the direction of the needle will be oblique to the equator, in consequence of the lines of equal electro-magnetic intensity being twice bent by the influence of the two great masses of continent. "The yearly and daily change," he observes, "must occasion yearly and daily variations. As to the variations comprehended in greater periods, we might perhaps attribute them to a *motion of the coolest points in such continents*, which, it appears, cannot remain the same for ever, because the currents of warmer air must principally be directed to such points." Analogous views have been propounded by M. Kupffer, in a memoir read in 1829 to the Russian Academy, in which he adopts explicitly Sir David Brewster's opinions of the existence of two cold poles distant from the pole of revolution. "But this distribution of temperature," says he, "*appears also to have a great influence on the distribution of the intensity of terrestrial magnetism.* This would no doubt be the case if it is true, as I have tried to show in another memoir, that terrestrial magnetism resides at the surface of the globe. We have here the choice between *two* hypotheses; either the earth should be considered as a magnet existing by itself, and then the intensity of its magnetism will be the inverse of its temperature; or it receives its influence from without, and is only like a piece of soft iron, to which the presence of a distant body communicates magnetism, and then the intensity of its magnetism will increase with its temperature. Though the first of these hypotheses has been hitherto generally adopted, yet the second acquires some probability from the discovery of the magnetic influence of the solar rays, and of the known relation between the diurnal variations of the declination of the needle and the course of the sun." The connection between the poles of maximum cold and those to which the isodynamical magnetic lines are related, is considered by Dr Dalton as a probable supposition. "If the idea," says he, "suggested by Sir David Brewster, in the *Transactions of the Royal Society of Edinburgh*, vol. ix., 1821, be correct (and there seems great reason to believe it to be so), namely, *that there are two poles of greatest cold in the northern hemisphere*, the above observation will enable us to see the natural cause of this remarkable fact. The lands within the arctic circle, in the absence of the sun, must depend upon the S.W. winds from the two great oceans for their winter heat. Those parts of the eastern and western continents which are most remote from the ocean, as measured along the curvilinear tracts of the current of air, must receive that air, in great measure, deprived both of its vapour and its temperature. Accordingly, it is found that the temperature of the N.E. parts of such continents exhibits the extreme of cold. Probably a latitude of 75° N., and a longitude of 90° E. and 90° W., would be found nearly equally cold, and to exceed any other place on the surface of the globe in this respect; and it would be a curious coincidence if Professor Hansteen's two supposed northern magnetic poles should be found in the same positions as the two poles of extreme cold."[1]

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[1] *Edinburgh Transactions*, 1820.

[2] *Edinburgh Encyclopædia*, art. "Thermo-Electricity."

Magnetism of the solar rays.

Dr Morichini.

Dr Carpi.

Mrs Somerville.

In a general history of magnetical discoveries, it may be proper to take some notice of the very curious experiments which have been made respecting the influence of the solar rays in the production of permanent magnetism, although, according to the generally received opinion, the existence of such an influence has not been established; but if the propriety of doing this had been doubtful, the observation made by M. Kupffer, as connecting this supposed property of violet light with terrestrial magnetism, would have removed the doubt. Dr Morichini, an eminent physician in Rome, was the first who announced it as an experimental fact, that an unmagnetized needle could be rendered magnetic by the action of the violet rays of the sun. His experiments were successfully repeated by Dr Carpi at Rome, and the Marquis Ridolfi at Florence; but M. d'Hombre Firmas, at Alais, in France, Professor Configliachi of Pavia, and M. Bérard of Montpelier, failed in obtaining decided magnetic effects from the violet rays. In 1814 Dr Morichini exhibited the actual experiment to Sir Humphry Davy, and in 1817 Dr Carpi showed it to Professor Playfair. A few months after Sir Humphry Davy witnessed the experiment, the writer of this article met him at Geneva, and learned from him the fact, that he had paid the most diligent attention to one of Morichini's experiments, and that he saw with his own eyes an unmagnetized needle rendered magnetic by violet light. The following account of the experiment made by Dr Carpi was given to us verbally by Professor Playfair, who approved of the statement of it which we drew up at the time:—"The violet light was obtained in the usual manner, by means of a common prism, and was collected into a focus by a lens of a sufficient size. The needle was made of soft wire, and was found upon trial to possess neither polarity nor any power of attracting iron filings. It was fixed horizontally upon a support, by means of wax, and in such a direction as to cut the magnetic meridian at right angles. The focus of violet rays was carried slowly along the needle, proceeding from the centre towards one of the extremities, care being taken never to go back in the same direction, and never to touch the other half of the needle. At the end of half an hour after the needle was exposed to the action of the violet rays, it was carefully examined, and it had acquired neither polarity nor any force of attraction; but after continuing the operation twenty-five minutes longer, when it was taken off and placed on its pivot, it traversed with great alacrity, and settled in the direction of the magnetical meridian, with the end over which the rays had passed turned towards the N. It also attracted and suspended a fringe of iron filings. The extremity of the needle that was exposed to the action of the violet rays repelled the N. pole of a compass-needle. This effect was so distinctly marked as to leave no doubt in the minds of any who were present, that the needle had received its magnetism from the action of the violet rays." In this state of the subject, Mrs Somerville made some simple and well-conducted experiments, which seemed to set the question at rest, from the distinct and decided character of the results. A sewing-needle an inch long, and devoid of magnetism, had one half of it covered with paper, and the other exposed to the violet rays of the spectrum five feet distant from the prism. In two hours it acquired magnetism, the exposed end exhibiting N. polarity. The *indigo* rays produced an equal effect, and the *blue* and *green* the same in a less degree. The *yellow*, *orange*, and *red* rays had no effect even after three days' exposure to their action. Pieces of blue watch-springs received a higher magnetism. When the sun's light fell upon the exposed end through blue-coloured glass, or through *blue* or *green* riband, the same magnetic effects were produced.

Mr Christie.

The experiments of Mr Christie, an account of which was read to the Royal Society a short time before Mrs Somerville's, confirmed her results to a certain degree, by a different mode of observation. He found that the compound solar rays possessed magnetic influence, and exhibited it in their effect of diminishing the vibrations of magnetized and unmagnetized steel needles, and also needles of copper or of glass, by making them oscillate in the sun's white rays. Mr Christie, however, has remarked, that, as his experiments have not succeeded on repetition

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[1] *Meteorological Observations and Essays*, second edition, 1834, p. 215.

Zantedeschi.

Baumgartner.

Barlocci.

by Sir William Snow Harris, when made in a vacuum, his results must have been owing to currents of air. In justice to Mr Christie, however, we must mention that Professor Zantedeschi repeated Mr Christie's experiments at Pavia under an Italian sun, with a needle a Paris foot long, and obtained a striking result. This needle, when drawn from its position of equilibrium, through an area of 90°, performed four oscillations in 30^s, the last of which had a semiamplitude of 70^s. In the solar rays it performed in 30^s four oscillations, the last of which had only a semiamplitude of 60°. When he exposed to the sun the N. pole, the semiamplitude of the last oscillation was 6° less than that of the first; while by exposing the S. pole this last oscillation became greater than the first. The experiments of Baumgartner and Barlocci tended to confirm these results. The former found that iron wires polished on a part of their length are magnetized by white solar light, exhibiting a N. pole on the polished part; and the latter has shown that an armed natural loadstone, which carried 1$\frac{1}{2}$ Roman pound, exhibited, after three hours' exposure to the strong light of the sun, an increase of energy equivalent to 2 ounces, or $\frac{1}{8}$th of a pound; while another larger one, which carried 5 pounds 5 ounces, had its strength nearly doubled by two days' exposure. Zantedeschi tried an artificial horse-shoe loadstone, which carried 13$\frac{1}{2}$ ounces; after three days' exposure to the sun it carried 3$\frac{1}{2}$ ounces more, and by continuing its exposure its power increased to 31 ounces. An oxidated magnet gained most power, and a polished one none. He found also that the N. pole of a loadstone exposed to the sun's rays concentrated by a lens acquires strength, while its S. pole, similarly exposed, loses it.

Ries and Moser.

Notwithstanding all these results, the general opinion seems now to be, that light does not exercise any decided effect in producing magnetism. The experiments of MM. P. Ries and Moser were made with needles both polished and oxidated, and also with wires half polished; and polarized as well as common light was made to fall upon them in a concentrated state, but no decided effect upon their number of oscillations could be observed; and they state that they think themselves justly entitled *to reject totally a discovery which, for seventeen years, has at different times disturbed science.*

Sir William Snow Harris. A.D. 1827.

In 1827 Sir William Snow Harris communicated to the Royal Society of Edinburgh his *Experimental Inquiries concerning the Laws of Magnetic Forces*, made with a beautiful and accurate instrumental apparatus, invented by the author for examining the phenomena of induced magnetism. With this apparatus he found that the magnetic development in masses of iron by induction is, *cæteris paribus, directly proportional to the power of the inductive force, and inversely as the distance;* and that the forces which magnets develop in a mass of iron at a given distance, within certain limits, may be taken as a fair measure of their respective intensities. From another series of experiments he has shown that the absolute force of attraction exerted between a magnet and a piece of iron varies with the power of the magnet, and consequently with the force induced in the iron, *cæteris paribus;* and that when the force induced in the iron is a constant quantity, while its distance from a temporary or permanent magnet is variable, *the absolute force varies with the distance.* This result was not only apparent when the magnetic force was varied by induction, but was also satisfactorily shown when varied by magnets of which the relative powers of induction were previously ascertained. Sir W. S. Harris made a number of nice experiments on the absolute force of attraction and repulsion between two magnetized bodies, which he found to be in the inverse ratio of the square of the distance. When, in the case of attraction, the magnets, however, were nearly approximated in relation to their respective intensities, the increments in the forces began to decline, and in some instances at near approximations the absolute force was in the simple inverse ratio of the distance. In the experiments with the repelling poles, the deviations from the regular force were still more considerable, and what is curious in this case, the force became less and less, until the polarity of the weaker magnet appeared to be so counteracted by induction, *that the repulsion was at length superseded by attraction.* Sir W. S. Harris next proceeded to determine the law according to which the forces are developed in different points of the longitudinal magnetic axis between the centre and poles of a magnet, and he found that it varied directly as the square of the distance from the magnetic centre; a law which is uniform in bars of steel regularly hardened and magnetized throughout. This law of distribution is exactly the same as that which has been given by Hansteen.

It is not necessary to mention here the numerous and valuable results obtained by Sir W. S. Harris in his more recent investigations; but there is one so new and interesting as to require special notice. We have already seen that Newton, Brook Taylor, and others, have obtained contradictory results respecting the law of magnetic force. Newton found the force to vary inversely as the cubes of the distance, and was therefore asserted by M. Biot[1] to have had very inaccurate ideas of magnetic phenomena. This criticism is founded on the common notion that magnetism is, like gravity, a central force; whereas Sir W. S. Harris has shown that the law of force given by Newton and others is deducible from their experiments, and that the assertion of Brook Taylor, "that magnetic attraction, as commonly observed, decreases quicker at greater distances than at smaller ones, and is different for different magnets," is not only true as an experimental fact, "but is the necessary result of the elementary laws of magnetism."[2]

Sir W. S. Harris has also published other two memoirs in the *Philosophical Transactions* for 1831, the first *On the Influence of Screens in arresting the progress of Magnetic Action*, and the second *On the Power of Masses of Iron to control the Attractive Force of a Magnet*, of both of which some account will be found in a subsequent section. In a later paper, *On the Investigation of Magnetic Intensity by the Oscillations of the Magnetic Needle*, he exposed an oscillating magnetic bar to a bright sunshine; and though he observed the effect observed by Mr Christie, which that philosopher ascribed to the influence of the sun's rays, yet he found that they all disappeared when the needle was made to oscillate in an exhausted receiver.

M. Haldat. A.D. 1830.

M. Haldat of Nancy communicated, in 1830, to the society of that city, the results of some interesting researches on the incoercibility of the magnetic fluid, or its power of exerting its influence through all bodies, even the most dense; a property which is not possessed by light, heat, or electricity. In this research he adopted various methods of observation, and interposed a great variety of substances; and from the numerous experiments which he made, he has drawn the following conclusions:—1. That the agent or fluid by which the magnetic phenomena are explained is incoercible in the present state of the science; 2. That iron, considered as presenting an exception to this law, coerces the magnetic influences only by acquiring itself the magnetic state; 3. That incandescence does not give to bodies the power of coercing the magnetic influence. In a previous memoir, M. Haldat had obtained some interesting results on the production of magnetism by friction. He found that all hard bodies may, by means of friction, assist in the decomposition of the magnetic fluid, if their action is promoted by the combined action of magnets which, by themselves, are incapable of producing it. If a piece of soft wire, for example, four inches long, and 1-25th of an inch in diameter, be placed horizontally between two bar-magnets with their opposite poles facing each other, and at such a distance that the wire cannot be magnetized, it will receive distinct magnetism by friction with all hard bodies, such as copper, brass, zinc, glass, hard woods, &c. M. Haldat employed the ingenious process of M. Gay-Lussac, of magnetizing soft iron by torsion, in neutralizing the wires before they were magnetized. If they are twisted after receiving magnetism, they will preserve the magnetism which they had received before torsion; but if, after being twisted, they are twisted in an opposite direction, they will become perfectly neutral.

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[1] *Edinburgh Encyclopædia*, vol. xiii., p. 270.

[2] *Rudimentary Magnetism*, part iii., p. 54.

M. Haldat likewise made some interesting experiments on the effect of the coercive force in steel on the magnetism produced by rotation, and he found that the force with which a revolving steel disc dragged round a magnetic needle was in the inverse ratio of the coercive force of the steel. When the discs were not hot, they had the same effect as those at the ordinary temperature. We owe also to M. Haldat an interesting paper on magnetic figures. Figures of any kind, when traced by the pole of a magnet on a plate of steel, are rendered visible by sifting upon the invisible tracings filings of steel, which arrange themselves in the most beautiful manner along the outlines of the figure which has been traced.

M. Quetelet.
A.D. 1830.

A series of very interesting experiments were published by M. Quetelet of Brussels, *On the successive degrees of Magnetic Force which a Steel Needle receives during the multiple frictions which are employed to magnetize it.* These experiments were made principally before 1830, but they were not given to the public till 1833. The following are the general results which were obtained by the author:—

1. When a needle or bar that had never been magnetized, is magnetized to saturation by the method of separate contact, the magnetic force acquired is a maximum in relation to the forces which can be given to the same needle or bar by the subsequent reversals of its poles.

2. The magnetic force which a needle can acquire becomes weaker in proportion as the reversal of its poles has been multiplied. The series of frictions which tend to bring back the poles to their primitive state are more efficacious than the others.

3. This difference between the forces which the needle acquires after the successive reversals of its poles, goes on continually diminishing, and converges towards a limit. It depends in general on the size of the needle in relation to that of the rubbing bars, as well as in its force of coercion.

4. A needle cannot receive all the magnetic force which it can acquire, if the frictions do not take place over all its surface; this becomes particularly sensible in the reversal of the poles.

5. The rubbing bars give (*cæteris paribus*) to bars of the same dimensions as themselves a magnetic force equal to that which they possess, and in bars of different dimensions the forces acquired are as the cubes of their homologous dimensions. The last part of this proposition was long ago established by Coulomb.

6. When we rub magnetic bars with other bars weaker than themselves, the force of the first diminishes in place of increasing; and it appears that the force becomes that which those latter bars would be capable of giving at the first by directly magnetizing them.

7. The relation which exists between the forces which a needle or a bar receives by successive frictions and the number of these frictions, may be expressed by an exponential formula of three constants.

One of these constants appears to change its value with the size of the bars which are magnetized, at least while these bars have a magnitude which does not exceed that of the rubbing bars, and while they are of the same quality of steel.

In this way we know beforehand the successive degrees of force which a bar takes at each friction, if we have previously determined the law of these augmentations for the same rubbing bars, and for any other bar which we get to serve as the modulus. If the bar which is rubbed has begun to be magnetized, we must calculate first the number of frictions to which this force corresponds, in order to be able to assign the rank of the subsequent frictions, and the magnitude of the corresponding magnetical forces.

8. When the rubbing bars are greater than the bar to be magnetized, from the first complete friction the force of magnetism is very nearly one-half of the force which the magnetized bar will finally possess.

After the twelfth complete friction, the magnetic force differs little from that which the rubbing bars can communicate.

We owe also to M. Quetelet two interesting memoirs on the magnetic intensity of different places in Switzerland, Italy, Germany, and the Low Countries.

Magnetic influence of the aurora borealis.

Dr Robison.

The influence of the aurora borealis on the magnetic needle, which was observed by Hiorter at Upsal, in 1741, and by Wargentin in 1750, had long induced philosophers to regard it as a magnetic phenomenon; and this was greatly confirmed by the fact that the S. end of the dipping needle points to that part of the heavens to which the rays of the aurora appears to converge. "The aurora borealis," says Dr Robison, "is observed in Europe to disturb the needle exceedingly, sometimes drawing it several degrees from its position. It is always observed to increase its deviation from the meridian; that is, an aurora borealis makes the needle point more westerly. This disturbance sometimes amounts to six or seven degrees, and is generally observed to be greatest when the aurora borealis is most remarkable.

"This is a very curious phenomenon, and we have not been able to find any connection between this meteor and the position of the magnetic needle. It is to be observed, that a needle of copper or wood, or any substance besides iron, is not affected. We long thought it an electric phenomenon, and that the needle was affected as any other body balanced in the same manner would be; but a copper needle would then be affected. Indeed, it may still be doubted whether the aurora borealis be an electric phenomenon. They are very frequent and remarkable in Sweden, and yet Bergman says that he never observed any electric symptoms about them, though in the meantime the magnetic needle was greatly affected.

Van Swinden.

"We see the needle frequently disturbed, both from its general annual position, and from the change made on it by the diurnal variations. This is probably the effect of auroræ boreales which are invisible, either on account of thick weather or daylight. Van Swinden says, he seldom or never failed to observe auroræ boreales immediately after any anomalous motion of the needle; and concluded that there had been one at the time, though he could not see it. Since no needle but a magnetic one is affected by the aurora borealis, we may conclude that there is some natural connection between this meteor and magnetism. This should farther incite us to observe the circumstance formerly mentioned, viz., that the S. end of the dipping needle points to that part of the heavens where the rays of the aurora appear to converge. We wish that this were diligently observed in places which have very different variations and dips of the mariner's needle."

Dr Dalton.

A valuable series of observations on the influence of the aurora borealis on the magnetic needle was made by Dr Dalton, at Kendal and Keswick, during seven years from May 1786 to May 1793, and has been published in his

Magnetic influence of the aurora.

Meteorological Observations and *Essays*, which appeared in 1793. During these observations he noticed the effect which they produced on the magnetic needle, and he was thus led to study the phenomena of the aurora, and to establish beyond a doubt the relation of all its phenomena to the magnetic poles and equator. His views and speculations on this subject we shall detail at some length in a future part of this article; but we shall at present give our readers a specimen of the observations which he made on the magnetic needle during the changes of an aurora.

The aurora appeared at Kendal Feb. 12, 1793, after 6^h P.M., flaming over two-thirds of the hemisphere. The beams converged to a point in the magnetic meridian about 15° or 20° to the S. of the zenith. The following were the changes which he observed in the needle and in the aurora:—

Time.	Variation.	Observations.
5^h 0^m P.M.	25° 5′ W.	
6 35 ...	24 49 ...	altitude of the clear space S. 35°.
6 42 ...	24 55 ...	altitude of ditto 20°, streamers bright, E.
6 50 ...	25 0 ...	streamers bright and active all over the illuminated part.
7 2 ...	25 28 ...	
7 5 ...	25 12 ...	
7 10 ...	24 40 ...	disappeared in the W., active E.
7 20 ...	24 35 ...	active about the zenith, light faint.
7 35 ...	24 45 ...	light faint.
8 0 ...	24 45 ...	strong light northward.
8 10 ...	24 45 ...	a large uniform still light covering half the hemisphere, with flashes now and then.
8 35 ...	24 47 ...	
9 15 ...	24 43 ...	streamers N.W., bright E.; clouds.
9 20 ...	24 43 ...	the *aurora* bursting out openly.
9 30 ...	24 50 ...	as fine and large a display of streamers as has appeared this evening.
10 0 ...	24 55 ...	
10 15 ...	24 57 ...	the light growing fainter and fainter.
10 35 ...	24 40 ...	

In these observations, the deviation produced by the aurora was 53′. In some cases, during the prevalence of auroræ, Dr Dalton did not observe any perceptible disturbance of the needle.

Professor Hansteen.

Professor Hansteen observes, that large extraordinary movements of the needle, in which it traverses frequently with a shivering motion an arc of several degrees on both sides of its usual position, are seldom, perhaps never, exhibited, unless when the aurora borealis is visible; and that this disturbance of the needle seems to operate at the same time in places the most widely separate. "The extent of such extraordinary movements," he adds, "may, in less than twenty-four hours, amount to 5° or 5½°. In most cases, the disturbance is also communicated to the dipping needle; and so soon as the crown of the aurora quits the usual place (the points where the dipping needle produced would meet the sky), the instrument moves several degrees forward, and seems to follow it. After such disorders, the mean variation of the needle is wont to change, and not to recover its previous magnitude till after a new and similar disturbance."

M. Arago.

Magnetic influence of the aurora.

Captain Foster.

Captain Home.

From an extensive series of accurate observations made by M. Arago at Paris since 1818, the needle was almost invariably found to be affected by auroræ that were seen in Scotland; and so striking was the connection between the two classes of facts, that the existence of the aurora could be inferred from the derangements of the needle. M. Arago has likewise discovered, that, early in the morning, often ten or twelve hours before the aurora is developed in a very different place, its appearance is announced by a particular form of the curve which exhibits the diurnal variation of the needle, that is, by the value of the morning and evening maxima of elongation. From a number of corresponding observations on the hourly declination made by M. Arago and M. Kupffer, who established at Kasan, near the eastern limit of Europe, one of Gambey's compasses, similar to that used at Paris, these philosophers were convinced that, notwithstanding a difference of longitude of above 47°, the disturbances produced upon the needle by the aurora took place at the same instant. It is a curious fact, however, and one yet unexplained, that during the frequent occurrence of the aurora at Port Bowen, Captain Foster did not observe any peculiar changes in the direction of the needle, although, from his great proximity to the magnetic pole, the diurnal change sometimes amounted to 4° or 5°; and, under such circumstances, the influence of the aurora ought to have been particularly conspicuous. Mr Christie is of opinion that the direction of the needle may be influenced by the electrical state of the clouds; and he found it to be so in a very distinct experiment which he made for the purpose. Captain Sir Everard Home had observed the same effect produced during thunder-storms; and, in two instances, he found that a needle came sooner to rest during a thunder-storm than it had done either previous or subsequent to it, the number of oscillations having been reduced in one case from 100 to 40, and in another from 200 to 120.

Sir George Back.

During the journey of Captain Sir George Back to the polar regions in 1833, 1834, and 1835, he found that the needle was generally affected by the aurora; and on one occasion the deviation which it produced was 8°. "For nearly a month, however" (previous to the 7th January 1834), he remarks, "the needle had not been perceived to be affected by the aurora, which, it may be proper to observe, was always very faint, apparently high, and generally confined to one point of the heavens."[1] Sir George Back repeatedly observed, that when the aurora was concentrated in individual beams, the needle was powerfully affected; but that it generally returned to its mean position when the aurora became generally diffused. On several occasions the needle was restless, and exhibited the vibrating action produced by the aurora when this motion was not visible; and Sir George Back states that he could not account for this, except by supposing the invisible presence of the aurora in full day.

Mr David Lyon.

The only metals which were formerly supposed to have a distinct and decided power, and were therefore called magnetic metals, are iron, nickel, and cobalt. Mr David Lyon[2] has endeavoured to show that these metals resemble one another, not only in their principal qualities, but in the numerical values of their qualities; and he adds, that whilst these three magnetic substances have the values above referred to nearly equal, there are no other substances in which the same values come very near or fall within those of the three magnetic substances. The values to which Mr Lyon alludes are the following:[3]—

	Specific Gravity.	Atomic Weight.	Atoms contained in a given space.
Nickel	8·27	739·51	1118
Iron	7·21	678·43	1062
Cobalt	7·8	738	1057

The preceding speculation, though ingenious, and deserving of attention, has, however, been overturned by some more recent observations of Dr Faraday. "*Cobalt* and *chromium*," says he, "are said to be both magnetic metals. I cannot find that either of them is so, in its pure state, at any temperature. When the property was present in specimens supposed to be pure, I have traced it to iron or nickel."[1]

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[1] Appendix to Sir George Back's *Narrative of the Arctic Land Expedition*, &c., p. 601.

[2] *London and Edinburgh Phil. Mag.*, December 1834, p. 415.

[3] M. Pouillet, in his *Elémens de Physique*, tom. iii., p. 89, refers to some remarkable analogies which he has observed between the distance of the atoms of bodies and their magnetic properties.

Dr Faraday.

Dr Faraday published in March 1836 some interesting observations[2] *On the General Magnetic Relations and Characters of the Metals.* He was of opinion that all the metals are magnetic, in the same manner as iron, though not at common temperatures, or under ordinary circumstances. He does not allude to a feeble magnetism, uncertain in its existence and source, but to a distinct and decided power, such as that possessed by iron and nickel; and his impression is, that there is a certain temperature for each metal (well known in the case of iron, beneath which it is magnetic, but above which it loses all power), and that there is some relation between this *point* of temperature and the *intensity* of magnetic force, which the body, when reduced beneath it, can acquire. Iron and nickel would then be no more exceptions from the metals in regard to magnetism, than mercury is in regard to liquefaction.

In order to investigate this point, Dr Faraday subjected various metals in their pure state to a temperature from 60° to 70° below the zero of Fahrenheit, but he could not detect in them the least indication of magnetism. The metals tried were the following:—

Arsenic.
Antimony.
Bismuth.
Cadmium.
Cobalt.
Chromium.
Copper.
Gold.
Lead.
Mercury.
Palladium.
Platinum.
Silver.
Tin.
Zinc.
Plumbago.

Dr Faraday next proceeded to compare iron and nickel with respect to the points of temperature at which they ceased to be magnetic. Iron loses all magnetic properties at an orange heat, and is then to a magnet the same as a piece of copper. Dr Faraday found that the point at which nickel lost its magnetic relations was very much lower than with iron, but equally defined and distinct. If heated and then cooled, it remained unmagnetic long after it had fallen below a heat visible in the dark; and almond oil can bear and give that heat which makes nickel indifferent to a magnet, its demagnetizing temperature being about 630° or 640° Fahr. In order to determine what relation the temperature which took from a magnet its power over soft iron had to that which would take from soft iron or steel its power relative to a magnet, Dr Faraday gradually raised the temperature of a magnet, and found that it lost its polarity rather suddenly when scarcely at the boiling point of almond oil, and then acted with a magnet as cold soft iron. It required to be raised to a full orange heat before it lost its power as soft iron. "Hence," he concludes, "the force of the steel to *retain* that condition of its particles which renders it a permanent magnet, gives way to heat at a far lower temperature than that which is necessary to prevent its particles assuming the *same state* by the inductive action of a neighbouring magnet. Hence, at one temperature, its particles can of themselves retain a permanent state; whilst, at a higher temperature, that state, though it can be induced from without, will continue only as long as the inductive action lasts, and at a still higher temperature all capability of assuming this condition is lost. The temperature at which polarity was destroyed appeared to vary with the hardness and condition of the steel. Fragments of loadstone of very high power were then experimented with. These preserved their polarity at higher temperatures than the steel magnet; the heat of boiling oil was not sufficient to injure it. Just below visible ignition in the dark they lost their polarity, but from that to a temperature a little higher, being very dull ignition, they acted as soft iron would do, and then suddenly lost that power also. Thus the loadstone retained its polarity longer than the steel magnet, but lost its capability of becoming a magnet by induction much sooner. When magnetic polarity was given to it with a magnet, it retained this power up to the same degree of temperature as that at which it held its first and natural magnetism."

M. Pouillet.

Some of the results observed by M. Pouillet[3] stand in opposition to some of the preceding statements. M. Pouillet considers it as certain that there are *five* simple magnetic bodies, viz.:—

Iron,
Manganese,
Nickel,
Chrome, and
Cobalt;

and in consequence of having observed some remarkable analogies between the distance of the atoms of bodies and their magnetic properties, he was led to suppose that the magnetic limit of different bodies ought to be found at very different temperatures. "I have, indeed," says he, "demonstrated by experiment,—1. That cobalt never ceases to be magnetic, or rather that its magnetic limit is at a temperature higher than the brightest white heat; 2. That chrome has its magnetic limit a little below the temperature of dark blood-red heat; 3. That nickel has its magnetic limit about 350° centigrade, nearly at the melting point of zinc; and, 4. That manganese has its magnetic limit *at the temperature of from 20° to 25° below zero.*[4] Experiments," continues he, "on these five magnetic bodies seem to prove, 1*st*, That heat acts upon magnetism only in consequence of the greater or less distance which it occasions between the atoms of bodies; and, 2*d*, That all bodies would become magnetic if we could by any action whatever make their atoms approach within a suitable distance."

Faraday. Para-magnetism and dia-magnetism.

The theory of universal magnetism, as deduced experimentally by Coulomb, has received great modifications from the discoveries of Dr Faraday. In consequence of using magnets of small power, Coulomb found that every body freely suspended between the poles of a magnet took what is called an axial position in a line joining the poles. Dr Faraday, however, has discovered that a large number of bodies place themselves in a position at right angles to the line joining the poles. To the substances possessing this property he has given the name of *diamagnetic;* and that of *diamagnetism* to the peculiar action exerted upon the molecules of bodies by the magnetic forces. Retaining the old name of *magnetism* for the general phenomena of the science, he adopts the following nomenclature:—

Magnetic	Paramagnetic	*Axial* direction, or *attractive.*
	Diamagnetic	*Equatorial* direction, or *repulsive.*

The nature of these forces may be more readily apprehended by supposing a fluid sphere to be placed between the magnetic poles: it would, if *paramagnetic*, be drawn out *axially* into a *prolate* spheroid; and if *diamagnetic*, it would be drawn out equatorially, and form an *oblate* spheroid. Dr Faraday found iron, nickel, cobalt, &c., to be paramagnetic; and bismuth, antimony, zinc, copper, silver, and gold, &c., to be diamagnetic. Hence it is obvious that the universal magnetism of Coulomb is incompatible with the discoveries of Dr Faraday. Among the most interesting results obtained by our distinguished countryman, is his discovery of the magnetic condition of gaseous bodies. Oxygen gas inclosed in a thin envelope was found to be paramagnetic, and drawn like iron into the axial line; while olefiant gas was diamagnetic, and repelled, like bismuth, equatorially. Guided by these results, Dr Faraday has been led to consider all space, whether devoid of matter or occupied by it, as traversed by lines of force operating through it; paramagnetic bodies concentrating parallel lines of magnetic force upon themselves, refracting them, as it were, like rays of light; and diamagnetic bodies expanding the same lines. In the one case the parallel lines are made to approach, and in the other to recede from one another.

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[1] *London and Edinburgh Phil. Mag.*, March 1836, p. 178.

[2] Ibid., p. 177.

[3] *Elémens de Physique*, 2d edit., tom. iii., p. 89, Paris, 1832.

[4] M. Pouillet remarks elsewhere, that manganese does not become magnetic till it is cooled down to 15° or 20° below zero. (*El. Phys.* iii., p. 18.)

Professor Gauss. A.D. 1833.

Researches on the intensity of magnetism were made by Professor Gauss of Göttingen, who has given an account of them in a treatise entitled *Intensitas vis Magneticæ Terrestris ad absolutam mensuram revocatis*, published at Göttingen in 1833. His object is to impart to magnetical observations the accuracy of astronomical ones. By observing the oscillations of a magnetized bar, he finds the product of the horizontal intensity of the earth's magnetism, and the static momentum of the free magnetism of the bar; and by eliminating the latter from the two equations, he obtains an absolute measure of the former, independent of the magnetism of the bar. The horizontal intensity thus found is then to be multiplied by the secant of the dip of the needle, in order to give the absolute intensity. In this inquiry Professor Gauss found it necessary to deduce from observation the true law of magnetic action, which, from a number of consistent and carefully made experiments, he found to be in the inverse ratio of the square of the distance. From a series of accurate experiments, Professor Gauss found the horizontal intensity at Göttingen, on the 18th September 1832, to be 1·7821; and taking the exponent of gravity in moving bodies at the place of observation as the unit of force, and using the Paris line and the Berlin pound, he found the absolute horizontal intensity to be 0·0039131; and as he found the dip at Göttingen on the 23d June 1832 to be 68° 22′ 52″, the absolute intensity of terrestrial magnetism will be

$$\text{Sec. } 68^\circ\ 22'\ 52'' + 0{\cdot}0039131.$$

Professor Gauss has proposed and put in practice a very accurate method of observing the daily variation of the needle, and of determining the time of vibration of a needle or magnetized bar. He fixes a plane mirror on the end of the bar, and perpendicularly to its axis, and by observing the reflected image of the divisions of a scale, by the aid of a theodolite placed at a distance, he is able to observe and to measure the minutest changes.

The magnetized bar employed by Gauss is of much larger dimensions than the bar of Prony's magnetic telescope; the small ones, which he uses as magnetometers, being four pounds weight, and the large ones twenty-five pounds; two of which, when fastened together, form the *apparatus or multiplier* of induction for rendering sensible and measuring the oscillatory movements predicted by a theory founded on Dr Faraday's great discovery. By this valuable invention of Professor Gauss, the observer is not under the necessity of approaching the magnetized bar, so that no disturbance is occasioned by the currents of air produced by the proximity of the observer's body, and the observations may be made in the smallest intervals of time.

With apparatus similar to that of Professor Gauss simultaneous observations were made in 1834 and 1836, at intervals of five or ten minutes, at Göttingen, Copenhagen, Altona, Brunswick, Leipzig, Berlin, Milan, and Rome. It appears from the graphic representation of the results, that the smallest inflexions of the horary curves are parallel, and consequently the disturbing causes which produce them simultaneous at Milan and Copenhagen, two of the places of observation, which have a difference of latitude of 10° 13′.

In giving an account of Professor Hansteen's labours, we have briefly noticed his journey to Siberia, and the erection of magnetic observatories by the Emperor of Russia, on the recommendation of Baron Humboldt; and we have also referred to the early researches of this distinguished philosopher. When travelling in the equinoctial regions of America during the years 1799–1804, Baron Humboldt had devoted much attention to the determination of the intensity of the magnetic forces, and of the dip and variation of the needle. Upon his arrival in Europe, he conceived the design of examining the progress of the horary changes of the variation, and the perturbations to which it is subject, by employing a method which had never been adopted on an extended scale. In a large garden at Berlin, he measured, particularly at the period of the equinoxes in 1806 and 1807, the angular alterations of the magnetic meridian, at intervals of an hour, often of half an hour, without interruption, during four, five, or six days, and as many nights. The instrument employed was Prony's magnetic telescope, suspended according to the method of Coulomb, and capable of being reversed upon its axis. It was placed in a glass frame, and directed towards a very distant meridian mark, the illuminated divisions of which indicated six or seven seconds of hourly variation. In these researches Baron Humboldt was struck with the frequency of oscillations whose amplitude extended beyond all the divisions of the scale, and which repeatedly took place at the same hours before sunrise. "These vagaries of the needle," says the baron, "the almost periodical return of which has recently been confirmed by M. Kupffer, in the account of his travels in the Caucasus, appeared to me the effect of a reaction of the interior of the earth towards the surface; I should venture to say, of *magnetic storms*, which indicate a rapid change of tension." With the view of investigating the causes of these disturbances, Baron Humboldt proposed to erect similar apparatus on both sides of the meridian of Berlin; but the political tempest in Germany, and his mission to France by the government, delayed the execution of his plan. M. Arago, however, as we have already seen, began and prosecuted the inquiry with singular success.

Baron Humboldt.

When Baron Humboldt again fixed his residence in Germany in 1827, he erected one of Gambey's compasses in a magnetic pavilion, without any iron, in the middle of a garden, and began a series of regular observations in the autumn of 1828. At his request, the Imperial Academy and the curator of the University of Kasan erected magnetic observatories at St Petersburg and Kasan; and the imperial department for mines established similar stations at Moscow, Burnaoul, and Nertschinsk. The academy, too, sent Mr George Fuss to Pekin, where he procured the erection of a magnetic pavilion in the convent garden of the monks of the Greek church. After Mr Fuss's return, M. Kowanko, a young officer of mines, continued the horary observations corresponding to those made in Germany and Russia. Admiral Greig established one of Gambey's compasses at Nicolaeff, near the Euxine. Baron Humboldt procured the establishment of a magnetic apparatus at the depth of thirty-five fathoms, in an adit in the mines of Freiberg in Saxony. Baron Von Wrangel was also provided with one of Gambey's compasses at Sitka, in one of the Russian settlements. M. Arago caused to be erected, at his own expense, one of Gambey's compasses in the interior of Mexico, where the soil is 6000 feet above the sea. The French minister of marine established a magnetic station in Iceland, and the necessary instruments were sent in the summer of 1836 to Reikiavig; and Baron Humboldt, at the desire of Admiral de Laborde, sent instruments to the Havannah in Cuba, to furnish a magnetic observatory under the tropic of Cancer.

Notwithstanding these insulated attempts to promote the study of terrestrial magnetism, so creditable to the individuals who made them, some more general and systematic organization of a national or European character was required. On the accession of Lord Grey's government to power in 1830, the writer of this article was requested by a distinguished member of it to suggest any measures which would be useful to science and improve the position of its cultivators. Among these, some of which were carried into effect, was the establishment of physical observatories in different parts of the British empire. The scheme was also brought before the British Association, but no decided step was taken till the year 1836, when Humboldt, in a letter to the Duke of Sussex, urged the erection of physical observatories in the British dependencies. The British Association and the Royal Society united their influence in the same cause; and the government, with an unexampled liberality, organized, as M. Kupffer expresses it, "the most gigantic scientific enterprise that had ever been conceived." The expedition to the South Pole, under Captain Sir James Ross, which sailed in September 1839, was agreed to; and arrangements were made for the establishment of magnetical observatories at Kew, Greenwich, Dublin, Toronto, St Helena, the Cape of Good Hope, and Hobart Town in Van Diemen's Land; and the court of directors of the East India Company authorised the erection of similar establishments at Simla, Singapore, Madras, and Bombay.

Magnetic Conference at Göttingen, A.D. 1839.

In order to organize this important enterprise, General Sabine and Dr Lloyd were deputed to repair to Berlin and Göttingen, to confer with Humboldt and Gauss; and also to St Petersburg, to put themselves in communication with the Russian government. This last journey, however, was rendered unnecessary. M. Kupffer was sent to Göttingen, by order of the emperor, to attend the conference, and to offer to the English philosophers the co-operation of the Russian observatories. The conferences of the magnetic congress began on the 15th October 1839, and the observations to be made at the different observatories were then finally arranged.

Appreciating the liberality of England, and stimulated by its example, the Russian government proceeded, under the direction of M. Kupffer, to erect observatories at different stations which had been fixed upon, and they were in due time completed at St Petersburg, Catherinebourg, Burnaoul, Nertschinsk, Tiflis, Sitka (on the N.W. coast of America), Helsingfors, and at the Russian mission-house in Pekin, in China. The English government furnished instruments for the observatories at Breslau, Hammerfest, Cairo, and Algiers; and magnetic observatories have been established at Berlin, Breda, Brussels, Copenhagen, Göttingen, Gotha, Hanover, Heidelberg, Leipzig, Marbourg, Milan, Munich, Philadelphia, Prague, and Upsal. The Austrian government has erected similar observatories under the superintendence of Dr Kreil; and Prussia has done the same at various stations from Memel to the Rhine.[1]

Although France, from reasons which it is not easy to understand, took no part in this great scientific movement, yet individual members of the Institute took an active part in establishing magnetical observatories on a limited scale. So early as 1823 M. Arago erected, in the garden of his observatory, a small building for magnetical observations; and at his request M. Kupffer made corresponding observations at Kazan in 1825 and 1826, thus anticipating the great movement afterwards made in England; but as no previous consent had been made respecting the days and hours of observation at these two stations, "it was only," as M. Kupffer observes, "by accident that the irregular motions of the two needles were shown to be simultaneous." Magnetical observations were carried on for some time at Montrouge, St Denis, Vincennes, and St Cloud, but they have not led to any important results.

The attention of the French government having been recently directed by M. Count de Vaillart, the distinguished minister-at-war, to the importance of meteorological observations in reference to the culture of cottons and other purposes in Algiers, the subject was brought before the Academy of Sciences in 1853, and more recently in 1855; when, after a violent opposition on the part of M. Biot[2] to the establishment of meteorological observatories, it was resolved to adopt the project of the government; and arrangements are now making for a complete system of magnetical observations at Paris and other places, and for making Algiers the centre of a similar system in the N. of Africa.

Researches of General Sabine.

Notwithstanding the rash and incorrect statement of M. Biot, that no real fruit had been obtained from the magnetic observations, most valuable results had been obtained several years before, with which he must have been acquainted. In the able hands of General Sabine, the Toronto and Hobart Town observations had led so early as 1851 to the discovery of important laws. In three interesting papers "On the Periodical Laws discoverable in the mean effects of the larger Magnetic Disturbance," he has shown that this disturbance, which is of large amount, and apparently of irregular occurrence, and to which the name of *magnetic storms* has been given, is, when studied in its mean effect, governed by periodic laws of systematic order and regularity, and exhibits periods whose duration is respectively,—1st, a solar day of 24 hours; 2d, a solar year of 365 days; and, 3d, *a period of about* TEN *of our solar years, corresponding both in duration, and in the epochs both of* maximum *and* minimum *variation, to the approximately* decennial *period discovered by Schwabe in the phenomena of the solar spots.*[3] Hence we may conclude that the sun is a great magnet, communicating to the earth its magnetic properties as well as its temperature, and having a force varying with the solar spots as indicating disturbances in its own atmosphere. Sir William Herschel endeavoured to show that the heat of the sun, as indicated by a good harvest or the low price of wheat,[4] varies with the solar spots; and it is a new argument in favour of the connection between the magnetic poles and those of maximum cold, that the magnetism of the earth, as well as its heat, varies with the number of spots or openings on the sun's atmosphere.

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[1] The Russian government has already (1856) published 14 quarto volumes, containing the magnetical and meteorological observations made at their observatories since 1840; and the British government has also published several volumes, containing the observations made at Toronto, St Helena, the Cape, and Hobart Town. These valuable works, many of them illustrated with numerous plates containing drawings of the instruments employed, and diagrams exhibiting to the eye the various results of observations, have been liberally presented to the principal scientific institutions in the Old and New World.

[2] M. Biot characterized the gigantic works published in Russia and England as "*large and expensive volumes filled with cyphers;*" and he had the hardihood to say "*that neither in Russia nor anywhere else has any* REAL *fruit been obtained from these costly publications,*" and that "*they can produce nothing but masses of disjointed facts, materially accumulated, and without any useful purpose in view, either for theory or its applications.*" (See *Comptes Rendus*, vol. xli., p. 1180. Dec. 31, 1855.)

[3] *Phil. Trans.* 1851, art. v.; 1852, art. viii. In these papers the periodical laws were deduced from the disturbances in the magnetic declination; but in a more recent memoir, read on the 14th February 1856, General Sabine has shown that the same laws regulate the disturbances of the magnetic inclination and the magnetic force.

[4] As the price of wheat depends upon many other causes than the summer heat, it is hardly an approximate measure of the temperature by which grain is ripened. It would therefore be advisable to compare the phenomena of the solar spots with the actual temperature of the seasons throughout the globe, in so far as it can be obtained from meteorological registers.

Influence of the moon on the magnetic needle.

Among the other grand results of our magnetic establishments we must rank the discovery of the moon's influence on the magnetic elements of the earth. Dr Kreil[1] seems to have first recognised the moon's influence upon the magnetic needle in the magnetical observations made at Prague in 1839 and 1840. Mr Broun obtained a similar result from the observations made at Makerstoun, in Scotland, and traced periodical laws, dependent not only upon the moon's hour angle, but upon her declination and distance from the earth. Believing that the sun influenced the earth's magnetism mainly, if not entirely, by its thermal influence, Dr Lloyd could hardly believe that the moon, whose heat was insensible, could exert any magnetic influence. Upon discussing the Dublin observations, however, he obtained results in accordance with those of Kreill and Broun in so far as the magnetic declination was concerned.[2] In a subsequent paper Dr Lloyd determined the law of the moon's action, the north pole of the needle deviating twice to the E. and twice to the W. in the course of the lunar day, and the maxima occurring one or two days after the syzigies, and the minima one or two days after the quadratures.[3] In a third paper he has shown that the moon exercises an influence upon the horizontal component of the magnetic intensity.[4] Dr Lloyd found that the effect of the moon upon the declination was to that of the sun as 1 to 13; and that the extreme variation of the morning range is 1′·85, and that of the evening one 1′·60; their mean variations being 1′·60 and 1′·20 respectively.

The discussion of the observations at Toronto by General Sabine has enabled him to determine with greater accuracy the influence of the moon on the earth's magnetism. From five years' observations made hourly, General Sabine has drawn the following conclusions:—"1. The three magnetic elements concur in showing that the moon exercises a sensible magnetic influence at the surface of the earth, producing in every lunar day a variation which is distinctly appreciable in each of the three elements by the instruments employed. 2. That the lunar diurnal variations in each of the three elements constitutes a double progression in each lunar day, the declination having two easterly and two westerly *maxima*, and the inclination and total force each two maxima and two minima between two successive passages of the moon over the astronomical meridian; the variation passing in every four times through *zero* in the lunar day. The approximate range of the lunar diurnal variation at Toronto is 38″·33 in the declination, 4″·4 in the inclination, and ·000012 parts of the total force. 3. That the lunar diurnal variation thus obtained, appears to be consistent with the hypothesis that the moon's magnetism is, in great part at least, if not wholly, derived by induction from the magnetism of the earth. 4. That there is no appearance in the lunar diurnal variation of the *decimal* period which constitutes so marked a feature in the solar diurnal variations."[5] These important results have been deduced from 106,619 observations, namely, 40,503 of the declination, 34,303 of the horizontal force, and 31,773 of the vertical force.

CHAP. II.—ON THE GENERAL PHENOMENA AND PROPERTIES OF MAGNETIC BODIES.

General properties of magnetic bodies.

A body is said to be magnetic when it has the power of attracting soft iron, either in the subdivided state of iron filings, or in large portions; or of attracting and repelling other magnetic bodies like itself: of taking a particular position when freely suspended, or moving on a pivot: and of communicating magnetism either temporarily to soft or permanently to hard iron in the form of steel. Hence we may arrange the general properties of magnetic bodies under the following heads:—

1. On the attractive power of magnetic bodies upon soft iron.
2. On the attractive and repulsive power of magnets over each other, or over iron either temporarily or permanently magnetized.
3. On the effect of masses of iron on the attractive force of a magnet.
4. On the polarity of magnetic bodies.
5. On the power of magnets to communicate magnetism to other bodies.
6. On the distribution of magnetism in artificial magnets.
7. On the effect of division and fracture on the distribution of magnetism.
8. On the magnetic charge.
9. On magnetic figures.

SECT. I.—*On the Attractive Power of Magnetic Bodies upon Soft Iron.*

Attraction of magnets over iron.

The natural magnet or loadstone was for a long time the only body considered as possessing magnetic properties. It is an ore of iron, of a grey colour, and a dark metallic lustre. Its specific gravity is about four and a half times that of water. It crystallizes in the form of the regular octahedron, and it consists of from 85 to 75 parts of iron, and from 15 to 25 parts of oxygen. It is found in almost every part of the world,[6] and often forms rocks of considerable magnitude; but different specimens of it possess very different powers of attraction.

Loadstone.

The smallest loadstones generally have a greater attractive power in proportion to their size than larger ones. They have been found of such strength, that though weighing only about 25 grains, they could lift a piece of iron about forty times heavier than themselves. A small magnet set in a ring, and worn by Sir Isaac Newton, is said, but we know not on what authority, to have been capable of lifting 746 grains, or 250 times its own weight; and it is stated by Cavallo, that he has seen a loadstone which weighed only about 6½ grains, which lifted a weight of 300 grains. A magnet weighing 38 lb., and which was found in 1781 to sustain above 200 lb., was presented to John V. of Portugal by the Emperor of China.

Natural loadstones often possess unequal powers of attraction in different parts of their mass, in consequence of want of homogeneity of structure and composition; and hence a portion has often been cut from a large loadstone which could lift a greater weight of iron than the large one itself, the portion detached having possessed the most suitable structure, and the other part having weakened the action of the powerful part by keeping the body to be lifted at a greater distance from those points where the magnetism was strongest. It is, no doubt, from a similar cause that small magnets have a greater proportional power than large ones, or that those of 2 lb. weight have seldom been found capable of lifting more then *ten* times their own weight of iron.

If we now take a natural loadstone L, however shapeless,

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[1] *Memoirs of the Imperial Academy of Sciences of Vienna*, 1850.

[2] *Proceedings of the Royal Irish Academy*, Feb. 28, 1853.

[3] *Ibid.*, May 9, 1853.

[4] *Ibid.*, Dec. 12, 1853.

[5] *Proceedings of the Royal Society*, June 13, 1856, vol. viii., No. 22, p. 216; and *Phil. Trans.*, 1856, art. xv.

[6] According to Norman, the best loadstones were those brought from China and Bengal.

General Properties of Magnetic Bodies.

and after rolling it in a quantity of iron filings afterwards withdraw it, we shall find that the filings are accumulated more abundantly in two opposite points A, B, than in any other, as shown in fig. 1. These two points A, B, are called the poles of the magnet, and are the points of greatest attraction. When either of these poles is held at a distance from the iron filings, the filings will be attracted to it, and will adhere with such force that it is difficult to brush them off.

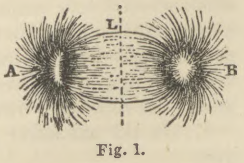

Fig. 1.

If we suspend a small needle of iron or steel by a fine linen or silken fibre, or balance it on a pivot, and bring the poles of the loadstone L near it, it will be attracted to it in the first case, or will oscillate on its pivot in the second case.

If we make the needle float on water in a glass tumbler, and bring any pole of L on the outside of the tumbler, the needle will be attracted towards the pole, notwithstanding the interposition of the glass; and by using the needle upon a pivot, it will be found that the attractive force of the loadstone is in no respect diminished by the interposition of any substance whatever, except iron; conductors and non-conductors of electricity having no effect whatever in stopping or diminishing the action of the loadstone, unless the interposed body be iron, or contains iron in any of its metallic states.

While the loadstone thus attracts iron, and all bodies containing it in a metallic state, these same bodies exercise a reciprocal attraction upon the loadstone, action and reaction being equal and opposite. The truth of this may be exhibited by suspending a magnet, and bringing into the vicinity of its poles a piece of soft iron. The magnet will be gradually attracted by the iron, in the same manner as if the iron had been suspended and a pole of the magnet held near it.

Armature of loadstones.

The power of natural loadstones is greatly increased by what is called an *armature*. After finding the poles of the loadstone, the opposite faces which contain them should be ground off, and the mass wrought into a regular shape, armed, as explained in chap. x., sec. 12.

SECT. II.—*On the Attractive and Repulsive Power of Magnets over each other, or over Iron either temporarily or permanently magnetized.*

Attraction and repulsion of magnets.

If we suspend near each other two loadstones, AB, A′B′ (as represented in fig. 2), by two threads T, T, we shall find by changing the relative position of their poles, AB, A′B′, that there are certain positions in which these poles attract each other, and others in which they are repelled. By marking the poles which attract each other, such as A, B′ and A′, B, we shall find that the poles which repel each other are A, A′ and B, B′, and that this mutual attraction and repulsion takes place under every change of circumstances.

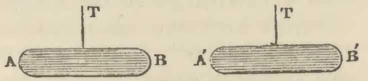

Fig. 2.

If we suspend a piece of soft iron *ab* from a loadstone AB, we shall find that the end *b* of the iron exercises the same attractive and repulsive power upon the poles A′, B′ (fig. 3), of a suspended magnet that B did; and in like manner, if the piece of iron *a′ b′* is suspended from the pole A′, the end *a′* will exercise the same attraction and repulsion upon the poles of a suspended magnet that A′ did.

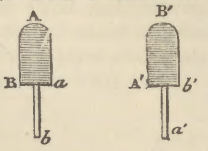

Fig. 3.

SECT. III.—*On the effect of Masses of Iron on the Attractive Force of a Magnet.*

General Properties of Magnetic Bodies.

Effect of masses of iron on the attractive force.

If we suspend a piece of iron C from the arm of a balance, it will be attracted by the pole P of a magnet A, and will descend towards P in virtue of this attraction. If we now place a mass of iron I close to A, the suspended iron C will rise, as if the attractive force of P were diminished. This power of the mass of iron I seems only to extend to a given point within the magnet A, the distance between the magnet and the iron remaining the same; for if the iron C is suspended above a point x at some distance from P, the action of I will not be felt at the point x, except by diminishing the distance between P and C, or by increasing the neutralizing power of the mass I.

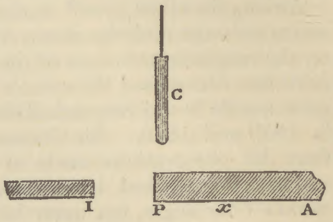

Fig. 4.

Sir William Snow Harris, to whom we owe this experiment, has shown that a similar effect is produced when the iron I is placed between the magnet P A and the suspended iron C, and also when I is placed below P. In the first of these cases I stops the attraction of P upon C, and acts as a screen.

Sir William has observed a very curious result of the action of iron upon a magnet. If we join the poles of a bar-magnet by a piece of soft iron, which is called its *keeper* or *armature*, the power of the magnet is preserved and increased; but if we envelope the bar completely in soft iron, its power is decreased. In a hollow cylinder of soft iron, Sir William placed a cylindrical magnet which fitted it accurately. The force of the inclosed magnet having been previously carefully measured, its power was found greatly diminished when it was withdrawn. Sir William found the decrease so great, that he believes the power of the magnet might be thus entirely annihilated by a careful arrangement of the experiment.

SECT. IV.—*On the Polarity of Magnetic Bodies.*

Polarity of magnets.

If we suspend a loadstone, as in fig. 2, or make it float upon water or mercury, by placing it on a thin plate of cork or wood, it will gradually change its place till it rests in a position where a line joining the poles A, B is nearly north and south. This is, generally speaking, the case in Europe; the end A, which points northward, deviating in some places from the meridian to the west, in some places to the east; while in other parts of the globe it points exactly to the north. The deviation of the loadstone from the meridian is called its *declination*, or *variation*. This property of the magnet is called its *polarity*, or *directive power*; and the pole A, which turns to the north, is called its *north pole;* and the pole B, which turns to the south, its *south pole.* It will now be found that the poles and magnets A, A′, or B, B′, which repel each other, are either both *north* or both *south* poles; and that the north and south poles attract each other. Hence there are in magnetism, as there are in electricity, two opposite powers or principles, namely, the *northern* and the *southern*, or boreal and austral magnetism; and, as in electricity, a *repulsion* takes place between the two powers of the *same* name, and *attraction* between the two powers of an *opposite* name.

The magnetism from which loadstones derive their polarity, or their tendency to direct themselves to particular points of the compass, is obviously derived in some way or other from the earth or its atmosphere; and hence it is called the *Magnetism of the Earth, or Terrestrial Magnetism,* which will be treated more fully in a future part of this article.

SECT. V.—*On the Power of Magnets to communicate Magnetism to other Bodies.*

Communication of magnetism.

We have already seen, that if a piece of soft iron is suspended to a magnet by the attraction of one of its poles, the iron becomes magnetic, but only during the time that it is in contact with the loadstone. But if we use a piece of hardened iron, or steel, *ab*, and suspend it as in fig. 3, it will be found to have acquired a permanent magnetism, the strength of which will depend on the power of the natural magnet AB, and on the time which the steel bar has been suspended. The pole *a* will be a *north* pole similar to A, and the pole *b* a *south* pole similar to B; and the little magnet *ab* will possess all the properties of the natural magnet, such as attraction for soft iron, and polarity; and its action upon another little steel magnet *a'b'*, made in a similar manner, will be the same as the action of two natural magnets upon each other. A steel magnet thus made is called an *artificial magnet;* and we shall in the sequel consider the magnets of which we speak as steel bars rendered permanently magnetic.

A little magnet *ab* has been made by a very simple process, namely, that of contact with the pole of a natural magnet; but there are more complex and efficacious methods, by which a very high degree of permanent magnetism can be communicated to steel, which will be fully explained in the practical part of this treatise.

In order to communicate magnetism from a natural or artificial magnet to unmagnetized iron or steel, it is not necessary that the two bodies be in contact. The communication is effected as perfectly, though more feebly, when the bodies are separated by space.

Magnetic induction.

If the *north* pole N of an artificial steel magnet A is placed near the extremity *s* of a piece of soft iron B, the end *s* will instantly acquire the properties of a *south* pole, and the opposite end *n* those of a *north* pole. The opposite poles would have been produced at *n* and *s* if the south pole S of the magnet A had been placed near the iron B.

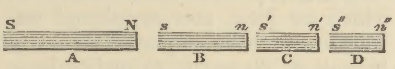

Fig. 5.

In like manner, the iron B, though only temporarily magnetic, will render another piece of iron C, and this again another piece D, temporarily magnetic, north and south poles being produced at n', s', and n'', s''.

The magnetism inherent in B, C, and D, is said to be *induced* by the presence of the real magnet A, and the phenomena are exactly analogous to the communication of electricity to unelectrified bodies by induction, the positive state inducing the negative, and the negative the positive, in the parts of a conductor placed in a state of insulation near an electrified body.

In order to show by simple experiments that soft iron is itself a magnet while placed near a magnet, let A be a magnet, and K a key held near its lower edge; a nail N will remain suspended by virtue of its induced magnetism; but if A is withdrawn, or K removed from A, the nail N will instantly fall, the induced magnetism diminishing with the distance.

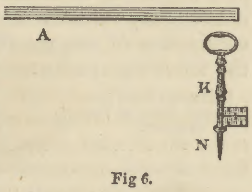

Fig 6.

If we hold the key K above a portion of iron filings, they will not be attracted by it; but if we then bring the magnet A near the ring of the key, as in the figure, the iron filings will instantly start up, and be attracted by the key.

Reaction of iron on magnets.

We have already noticed, in Sect. I., that the iron attracted by a magnet reacts upon the magnet, and attracts it in return. The same is the case with a bar of iron on which magnetism is induced. It reacts on the magnet which induces its magnetism, and increases its magnetic intensity. Hence we derive a distinct explanation of the remarkable facts, that a magnet has its power increased by having a bar of iron placed in contact with one of its poles, and that we can gradually add more weight to that which is carried by a magnet, provided we make the addition slowly and in small quantities; the power of the magnet being increased by the reaction of each separate piece of iron that it is made to carry.

Consecutive poles.

If the bar of iron on which magnetism is induced is long, and the strength of the magnet great, a succession of poles is produced along its length, a north pole always following a south pole, and *vice versa.*

Magnetic attraction and repulsion explained.

These facts enable us to explain the phenomena of magnetic attraction and repulsion, which are necessary consequences of magnetic induction. The magnet attracts a piece of iron by inducing an opposite polarity at the end in contact with it, and the two opposite principles attract each other. In like manner, the north pole of one magnet attracts the south pole of another, and similar poles repel each other, in consequence of the attraction and repulsion of the opposite or similar principles. The attraction of iron filings is explained in the same manner. The particle of iron next the magnet has magnetism induced upon it, and it becomes a minute magnet, like B in fig. 5. This particle again makes the next particle a magnet, like C, and so on; the opposite polarities in each particle of the filings attracting one another, as if they were real magnets.

In comparing the amount of the *attractive* force of two *dissimilar* poles of two magnets with the amount of the *repulsive* force of the two similar poles, it has been found that the former force is considerably greater than the latter. This result is a necessary consequence of the inductive process above described. When the two attracting poles are in contact, each magnet tends to increase the power of the other, by developing the opposite magnetisms in the adjacent halves, and thus increasing their mutual attraction. But when the two repelling poles are brought into contact, the action of each half brought into contact has a tendency to develop in that half a magnetism opposite to that which it really possesses, and thus to diminish the two similar principles, and weaken their repulsive power. This injurious influence of opposite poles upon the repulsive power of the magnets in action is finely exhibited when one of the magnets is very powerful, and the other very weak. When the two similar poles are held at a moderate distance a repulsion is distinctly exhibited; but when they are brought into contact, the stronger *attracts* the weaker magnet, an effect which is produced by its actually destroying the similar weak magnetism in the half next it, and inducing in that half the opposite magnetism, which, of course, occasions attraction.

When the magnet A and the piece of iron B are placed in the same straight line, as in fig. 5, the pole N acts favourably in inducing south polar magnetism at *n*, and north polar at *s;* but it is evident that the remote pole S must tend to weaken the inductive force of N, by inducing, though in a feeble degree, north polar magnetism at *n* and south polar at *s*. If the soft iron B is placed as in fig. 7, the induced magnetism will be nearly as strong as before, the greater proximity of N tending to produce south polar magnetism in *n*, being compensated by the increased proximity of S tending to produce north polar magnetism in *n*. In the inclined position C the induced magnetism is still stronger, as S acts more powerfully upon *n;* and when the two are parallel, as in fig. 8, the two bars or magnets are in the position most favourable for developing and sustaining the magnetism which they receive or possess.

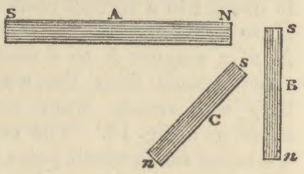

Fig. 7.

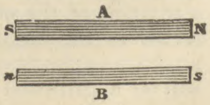

Fig. 8.

General Properties of Magnetic Bodies.

Hitherto we have considered the natural and artificial magnet as producing magnetism in soft or hard iron, distributed in the same manner as in the inducing magnet; but by the action of one or more magnets we can distribute the magnetism in various ways, as follows:—

In the case of bars, we may have a north pole in the middle of it, and a south pole at each extremity. Thus, in fig. 9, if the magnet NS has its north pole N placed opposite the middle of the soft iron bar *nn*, this bar will have a south pole at *s*, and north poles at *n*, *n*. The very same effect will be produced if, as in fig. 10, we place the soft iron bar B between two magnets A, C, whose north poles N, N, tend to produce south poles at *s*, *s*, and consequently northern polarity in the middle at *n*. In the preceding case, a south pole may be produced in the middle, and north poles at the ends of the bar, by placing the south poles of the magnets where the north poles are placed.

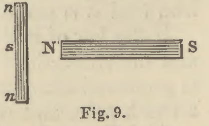

Fig. 9.

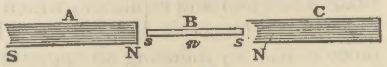

Fig. 10.

In like manner, a piece of soft iron *ss*, *ss*, of the form of a cross, will have south poles at *s*, *s*, *s*, *s*, if the south pole S of a magnet A is placed on or near its centre, as in fig. 11; as it may be conceived to consist of two bars *ss*, *ss*. For the same reason, if a circular plate of soft iron is substituted in place of the cross *ss*, *ss*, and the south pole S of the magnet placed upon or near its centre, that centre will be a north pole, and every point of the circumference of the plate will be a south pole.

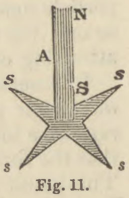

Fig. 11.

A very instructive experiment, founded on magnetic induction, is exhibited in fig. 12, where several soft-iron wires or slender bars *sn*, *sn*, *sn*, are suspended at the north pole N of a magnet N. Each of the ends *s*, *s*, *s*, becomes a south pole by induction from the action of the north, and consequently the lower ends *n*, *n*, *n*, north poles. The south poles *s*, *s*, *s* have a tendency to repel each other, but are prevented from yielding to their repulsive forces in consequence of their strong adhesion to the north pole N. The north poles *n*, *n*, *n*, however, are free from this restraint, and exhibit their mutual repulsion by their diverging as shown in the figure. Hence we see the reason why rows of iron filings adhering to each other, when attracted by a magnet, keep separate from each other by the repulsive forces of the similar poles.

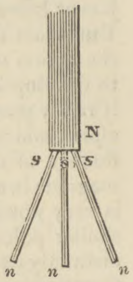

Fig. 12.

In the following form of the experiment given by Cavallo, the repulsion of both poles is well illustrated. If we suspend two short pieces of soft iron wire *ns*, *ns* by threads, they will hang in contact in a vertical position. If we now bring the north pole N of a magnet A to a moderate distance from the wires, they will recede from each other, as in fig. 13. The ends *s*, *s* being made south poles by induction from the north pole N, will repel each other, and so will the north poles *n*, *n*. This separation of the wires will increase as the magnet A approaches nearer them; but there will be a particular distance at which the attractive force of N overcomes the repulsive force of the poles *s*, *s*, and causes the wires to converge, as in fig. 14, the north poles *n*, *n*, still exhibiting their mutual repulsion.

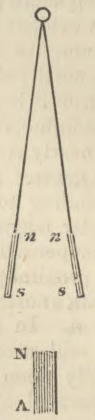

Fig. 13.

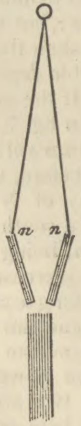

Fig. 14.

General Properties of Magnetic Bodies.

The neutralization or destruction of induced magnetism, by two equal and opposite magnetic actions, is shown in the following experiment, given by Dr Robison. If we take a forked piece of soft iron CDE, and suspend it by the branch D from the north pole of a magnet B, it will be magnetized by induction, and will carry a key at its lower end E, which will be a north pole. If we now apply to the other branch C the south pole S of another and equal magnet A, the key will instantly drop off. This obviously arises from the south pole S inducing a south pole at E, which either destroys or neutralizes the north polar magnetism previously induced by N.

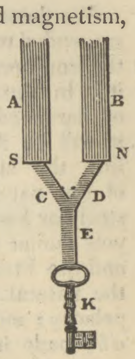

Fig. 15.

Sect. VI.—*On the Distribution of Magnetism in Artificial Magnets.*

Distribution of magnetism.

It is very obvious from the preceding experiments that in regular magnets, with a north pole at one end and south pole at the other, the two kinds of magnetism, north polar and south polar, are equally and regularly distributed, the one occupying one-half of the magnet, and the other the other half. It is obvious, also, that each kind of magnetism has no intensity at the centre of the magnet, or its middle part, and that it increases, according to some regular law, from that point towards the two poles at the extremities of the magnet.

Coulomb's experiments.

The first person who determined the law of distribution which we have now mentioned was M. Coulomb. The magnet which he employed for this purpose was a cylinder 2 lines in diameter, 27 inches long, and its weight 1946 grains; and he ascertained the intensity of magnetism at each point, from its middle to its extremity, by observing the number of oscillations which a small magnetic needle performed in a minute, when it was made to oscillate before different points of the wire. He had previously observed the number of oscillations which the same needle performed out of the sphere of the magnet, and he considered the magnetic intensity as proportional to the difference of the squares of those two numbers of oscillations. The first needle which he employed was 3 lines in diameter and 6 lines long; and it was made of such a size, and of such hardness, that its magnetism should not be perceptibly altered by the action of the wire during the experiments; for if any change did take place, the results obtained at different points of the magnet could not be compared. The great length of 27 inches was given to the magnet, in order that its remoter pole might be so distant from the needle that it would be unnecessary to make any allowance for its action upon the oscillations of the needle. In this way Coulomb obtained the following results:—

Distances from the North Pole of the Magnet.	Observed intensity of the Magnetism at these distances.
0	165
1	90
2	48
3	23
4, 5	9
6	6

The distribution of the magnetism is exhibited in fig. 16, where AN is half of the magnet, and N its north pole; and the ordinates to the curves represent the intensities in the preceding table.

These experiments were repeated by Coulomb, with magnets of the same shape and diameter, but of a less length, all other circumstances being unchanged, and he obtained nearly the same results for the three inches of the magnet

General Properties of Magnetic Bodies.

nearest N; and hence he concluded, that whatever was the length of the magnet, provided it was greater than 6 or 7 inches, the 3 inches at both its north and south poles gave always the same results as the 27-inch magnet. From this point towards the centre, the magnetism became weak and insensible in all of them; and, in very long magnets, he even found that the ordinates sometimes passed from positive to negative.

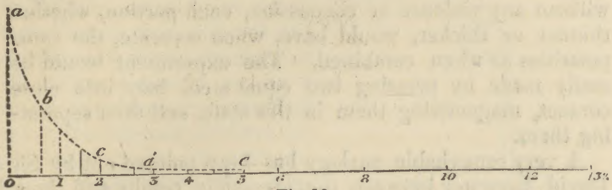

Fig. 16.

M. Biot has remarked that the curve of intensity, as determined by Coulomb, results from the combination of two logarithmic curves ACB′, A′CB, which, setting out from each pole A, B of the magnet AB, would have their ordinates equal and in an opposite direction, as shown in fig. 17. The intensities calculated upon this supposition agree exactly with the observed results.

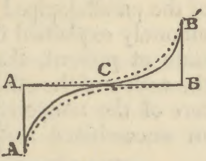

Fig. 17.

Becquerel's experiments.

As Coulomb had examined the distribution of magnetism only in magnets of considerable size, M. Becquerel[1] was desirous of ascertaining if the law was observed in steel wires of a small diameter, such as $\frac{1}{80}$th of a millimetre, or $\frac{1}{2000}$th of an inch. In order to procure such wires, he incased a steel wire, 1 millimetre in diameter, in a cylinder of silver, and having drawn out the whole into a wire, the silver was removed by means of boiling mercury. He employed the method used by Coulomb in determining the law of distribution; but on account of the fineness of the wires, and the weakness of the magnetism which they acquired, he was obliged to make some changes in the method. He obtained, however, the very same results as those given by Coulomb.

Kupffer's experiments.

A number of interesting experiments on the distribution of magnetism were made by M. Kupffer of Kasan,[2] by means of the method of Coulomb. He employed a flat and very narrow needle 12 millimetres long, and he placed it at a horizontal distance of 3 decimetres from a cylindrical bar-magnet of cast steel not tempered, 607 millimetres long, and 12½ millimetres thick. He began his experiments with magnets that possess a weak degree of magnetism. In magnetizing them, he rubbed the steel bar perpendicularly on the north pole of a very strong artificial magnet, and replaced the bar vertically before the needle, the north pole of the bar being uppermost. He found that the south pole was stronger than the north, and that the point of indifference, or the neutral point, was nearer the stronger pole than the other. Upon reversing the magnet, the magnetic intensities of its different points increased, and the neutral point approached the middle of the magnet. These changes were produced successively, and the magnet did not attain its final state till it had remained some time in the same position. Kupffer observed, that whenever the magnetic intensities of the bar increased, the neutral point slowly approached the middle point; that this point was always nearer the stronger pole; that a bar magnetized vertically was always more powerful when its north pole was downwards; and that a bar magnetized by the method mentioned above was always strongest in the pole immediately produced by that of the magnet.

After detailing his observations with a bar magnetized to saturation, he proceeds to determine the influence exercised by the form of the extremities of the bar on the magnetic intensity, and on the position of the neutral point. A cylindrical bar of steel, cast, but not tempered, having been rounded at one of its ends, and magnetized to saturation, was placed 14 centimetres from a magnetic needle, and in the line of its direction. When its north pole was directed to the south, the force of the rounded north pole was 2·0319, and that of the south pole was 2·1558. In the opposite position of the bar, the magnetic force of the north pole was 2·2198, and that of the south pole 2·3006, the neutral point being in the middle.

The rounded end of the bar was now filed to a point, and made sharper and sharper in every successive experiment, after being each time magnetized to saturation. The force of the sharpened pole diminished with its acuteness. The neutral point receded always from this extremity.

This interesting subject has been more recently investigated by Hansteen and Sir W. S. Harris. According to Hansteen, the intensity of any magnetic particle in a bar magnet situated in the axis, is directly as the square of its distance from the middle point of that axis, or the centre of the magnet; while it results from Sir William Harris's experiments "that the magnetism in different points of a regularly tempered and magnetized steel bar is directly as the distance from the magnetic centre; whilst the reciprocal force between any given point and soft iron is as the square of the distance from that centre."[3]

Distribution of magnetism in the interior of magnets. Coulomb's experiments.

In order to ascertain the distribution of magnetism in the interior of magnets, Coulomb formed sixteen rectangular magnets out of the same piece of steel. Each was 6 inches long, 9½ lines wide, and 382 grains in weight. They were annealed at a white heat without being tempered, in order that he might be certain of having them always in the same state. He magnetized them all to saturation, and formed bundles with a certain number of them, similar poles being placed together. The magnets in each bundle were bound tightly together with a strong silk thread. Each bundle was then placed in a torsion balance, and placed 30° out of the magnetic meridian. The force of torsion necessary to retain it in this position was a measure of its magnetic intensity. The following were the forces or degrees of torsion necessary to keep the different bundles at rest:—

	Degrees of Torsion.
1 magnet	82°
2 magnets united	125
4 magnets „	150
6 magnets „	172
8 magnets „	182
12 magnets „	205
16 magnets „	229

Hence it follows that the magnetic force of each bundle increases in a ratio much less than that of the number of plates.

Coulomb next determined the magnetic state of each of the magnets composing the bundles of eight and sixteen magnets; and he found that the two outermost magnets, those which formed the surface of the bundles, had a much greater force than the rest.

The first had a force which measured	46
The second	48
And the mean force of all the rest was	30

A single magnet had its directing force 82°, while for sixteen of them united the mean directing force of each was only 14°·3, that is, about the sixth part of the other.

In examining the bundle of eight magnets by the method of oscillation, he found that the two outermost performed twenty oscillations in 90½ minutes, while all the rest performed the same number in from 211 to 278 nearly, showing the weakness of their magnetism. It is curious that the outermost but one had its poles reversed.

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[1] *Ann. de Chimie*, tom. xxii., p. 115; Becquerel, *Traité Experimentale de l'Electricité et de Magnetisme*, tom. i., p. 365.

[2] *Ibid.* tom., xxvi. p. 50.

[3] *Rud. Mag.*, part iii., p. 60.

Coulomb also found that a bundle of magnets will take nearly the same degree of magnetism as a single magnet of the same shape and weight; which leads us to believe that, in magnets of one piece, the magnetism diminishes from the surface to the centre, as in the preceding bundles of magnets.

SECT. VII.—*On the Effect of Division and Fracture in the Distribution of Magnetism.*

Effects produced by breaking magnets.

As no natural or artificial magnet has ever been seen with only one pole, or one kind of magnetism, it became interesting to determine experimentally the distribution of magnetism in a part of a magnet cut from its north or south extremity. This experiment has been often made, both by cutting it through at the middle or neutral point, or by cutting or breaking off a portion from the end of it. If NS, for example, is a magnet, N its north and S its south pole, and ACB the curve representing the intensity of its magnetism; then, if we cut it through the middle, C, each half *ns*, *n′s′* will be a complete magnet, with a north pole at *n*, and a south one at *s*, and their neutral points at *c*, *c′*; the curves at *acb*, *a′c′b′*, representing the distribution of their north and south polar magnetism, being similar to the curve ACB of the large magnet of which they are the halves.

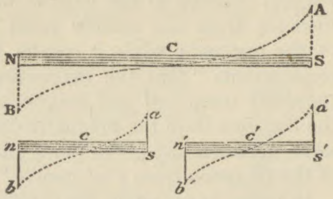

Fig. 18.

When Æpinus made this curious experiment, he did not divide the magnet in two, but he set two steel bars end to end, and magnetized them as one magnet; so that this compound magnet had its magnetism distributed as in a single bar, like NS, fig. 18. He then separated them, and found that each bar was a perfect magnet, with two poles. Dr Robison repeated this experiment successfully on some occasions; but he sometimes found indications of the compound magnet acting as two magnets. We are persuaded that this arose from an imperfect union of the two bars, and not from any defect in Æpinus's experiment. The united ends of the bars should be ground together, so as to be kept in perfect contact, and preserved in this state by a powerful pressure during the time that they are magnetized. If this be done, we have no doubt that they will act on iron filings, and throw them into curves, as if they were a single bar, and will, by examination with a fine needle, exhibit the same regular distribution of magnetism which takes place in the most perfect magnet.

Upon the separation of the magnets thus united, Æpinus found that two poles were instantly developed in each half, but that the neutral points *c*, *c′*, fig. 18, were nearer the interior poles *s*, *n′*; or, what is the same thing, nearer the original neutral point C, than to *n* and *s′*. In the space of about a quarter of an hour, it had, however, advanced nearer to the middle points *c*, *c′*, and continued for some hours, and sometimes for days, to advance to these points, which it finally reached, thus completing the regular distribution of the two opposite magnetisms.

Some observations, but not very accurate ones, have been made on the division of magnets in the direction of their lengths. According to Dr Derham, the two portions sometimes have contrary, and sometimes the same poles, as when they were united. When one portion was much thinner than the other, the thinner portion had generally its poles reversed. This experiment does not possess much interest; for it can scarcely be doubted that, if we could divide a magnet in the direction of its length without any violence or concussion, each portion, whether thinner or thicker, would have, when separate, the same polarities as when combined. The experiment would be easily made by pressing two equal steel bars into close contact, magnetizing them in this state, and then separating them.

Analogy between magnets and unannealed glass.

A very remarkable analogy has been pointed out by Sir David Brewster between the preceding results and those which he has obtained with parallelopipeds of glass, which received the doubly refracting structure by being quickly cooled on all their surfaces from a state of red heat. This change is analogous to that of temper in a magnet; and the effect of it is to produce a certain development of positive and negative double refraction throughout the whole of the parallelopiped of glass. These phenomena will be minutely explained in our article on OPTICS; but we may state at present, that the structure of the glass modifies the action of the ether which it contains, just as the structure of the tempered steel keeps the two magnetisms in an uncombined state. This is shown in fig. 19, where AB is a thick plate of glass quickly cooled. The middle portion of it P has positive, and the external portions N, N, negative double refraction. The density of the ether in each of these portions varies according to a regular law; and the intensity of the doubly refracting force, at different points both of the positive and negative structures, is represented by a curve formed by the superposition of a straight line and a parabola. If we now cut the parellelopiped of glass into two halves, through the dotted line AB, fig. 19, each half will have the same structure as the whole, as shown in fig. 20; the parts that were formerly *positive* being now *negative*, and *vice versa;* and the intensity of the doubly refracting force in each half will be represented by the ordinates of a curve formed by the superposition of a straight line and a parabola. This fact is in perfect analogy with the magnetic one, and there are many other remarkable points of resemblance.

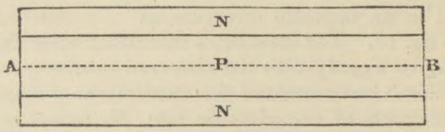

Fig. 19.

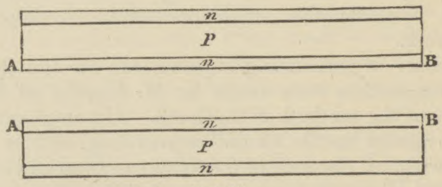

Fig. 20.

SECT. VIII.—*On the Magnetic Charge.*

The subject of magnetic charge, or the quantity of magnetism in a bar-magnet under a given attractive force, which may be termed intensity, has been investigated by Sir William Harris. He has shown, in the following interesting experiment, that this intensity is independent of the mass of the magnetized body, and, therefore, that magnetism, like electricity, is entirely confined to the surface.

Let AB be a cylinder, of soft iron 2 inches long, $\frac{1}{2}$ an inch in diameter, and $\frac{1}{10}$th of an inch thick. A solid cylinder of soft iron, *ab*, is made to fit into AB like one of the draw-tubes of a telescope, so that it can be pulled out to any point *c*, or altogether. Fix a magnet M, at a constant distance p, beneath AB, and bring the whole under the trial cylinder t of a magnetometer, in order to measure the quantity of magnetism induced upon the cylinder by the magnet M. The distances p and t being regulated by a divided scale, the intensity or force on t induced upon AB and ab, or in mass, was 10°. The cylinder ab being now pulled out to c, the intensity or force on t gradually declined; and when ab was pulled out as far as possible, the intensity was reduced, to 5° or $\frac{1}{2}$. When the interior cylinder was wholly removed the intensity became 10°, the same as when the two cylinders formed one. Hence it follows, that magnetism resides on the surface, a result confirmed by the fact that a hollow cylinder of tempered steel may be magnetized as powerfully as a solid cylinder of the same dimensions.[1] Sir W. Harris has found that the intensity or attractive force is as the quantity of magnetism, as in electricity.

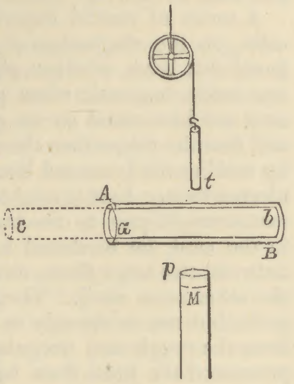

Fig. 21.

SECT. IX.—*On Magnetic Figures.*

Magnetic figures.

In our article on ELECTRICITY we have given an account of the beautiful clectrical figures discovered by M. Lichtenberg, and which form one of the most interesting popular experiments in that science. We are indebted to M. Haldat of Nancy for the analogous discovery of magnetic figures, which may be easily produced. For this purpose, he employed plates of steel from eight to twelve inches square, and from one-twentieth to one-eighth of an inch thick. The plates which he used were of that kind of steel which is used for the manufacture of cuirasses, so that it did not require to be tempered, being sufficiently hard to preserve the magnetism communicated to it. Figures of any kind may be traced on the surface of the steel plate, either by one magnet or by several combined; and the best form for this purpose is that in which the poles are rounded. In this way we may write upon a steel plate the name of a friend, or sketch a flower or a figure, with the extremity of a magnet. If it is a south pole that we use, all the traces which it makes will have north polar magnetism; and if we shake steel filings upon the plate out of a gauze bag, the filings will arrange themselves in the empty spaces between the lines traced by the pole of the magnet, and thus represent, in vacant steel, the name which has been written, or the flower or figure which has been sketched. "These figures," says M. Haldat, "have a perfect resemblance to those which are formed on the surface of non-magnetic plates,—viz., wood, card, glass, or paper, under which a magnet is placed. The resemblance between the two sorts of figures, when the magnets and the parts magnetized have the same form, is not only exact in the whole figure, but even in the smallest details. The filings collect at the parts where the magnetism is most intense, they arrange themselves in pencils and radii, and form the same curves which we have represented above (see fig. 1). These curves, and pencils, and rays, so similar at the two poles of the same magnet, have such a resemblance that they do not allow us to distinguish the two parts from one another."

M. Haldat likewise produced these curves by interposing between the tracing magnets and the steel plates solid non-magnetic bodies, such as cards, glass, and even metallic plates that are not ferruginous. This method of producing magnetism in the steel plate by induction gives the same figures; but, in order to be efficacious, the magnet must have its pole carried parallel to and at a small distance from the plate of steel, and must repeat its traces, in order that the magnetism may be sufficiently developed. For rectilineal figures, M. Haldat employed rules with grooves, which keep the motion and distance of the bar invariable; for curvilineal figures he interposed some thin and uniform plate, and varied the distinctness of the figures by varying the distance of the tracing pole of the magnet.

Magnetic figures.

In sifting the iron filings upon the steel plate, a gentle vibration of the plate, by tapping its edge with the ring of a small key, will assist the filings in taking their proper places; but we must avoid such vibrations as will produce regular acoustic figures, unless we wish, as M. Haldat found to be practicable, to unite the magnetic with the acoustic figures, which produces very interesting and varied forms.

M. Haldat found that the magnetic figures will continue for six months. In order to remove the magnetism which produces them, he recommended the heating of the plate upon red-hot charcoal, till it is brought to the straw-yellow temperature. In order to render the repolishing of the plate unnecessary, M. Haldat tinned it, and the temperature at which the tin melted, when it was required to efface the magnetism, indicated the necessary heat. M. Haldat employed also another method which is perhaps the best. He placed the steel plate upon a block of wood, and by repeated and violent blows of a wooden hammer he removed the magnetism of the plate, the figures gradually becoming weaker and weaker when the experiment was tried with it in different stages. The effect was often produced in three or four minutes.

As the figures traced on the steel are nothing more than magnets of different forms, and are surrounded on all sides with a substance capable of acquiring the magnetism which may be developed by communication, we might expect, as M. Haldat remarked, that this means of communication between the opposite poles of the magnets would bring them into a neutral state. This, however, is not the case; and the portion of the metal which surrounds the magnetic figure performs the part of the *armature* of a loadstone, and the magnetism is thus kept up. If the figure be a simple rectangle, like that of a bar-magnet, the state of the plate, examined with a small needle, is exactly the same as a bar-magnet, and the parts which surround this magnetic portion are in a neutral state, as if unconnected with the rectangular space; from which it follows that the magnetic virtue, which communicates itself so easily by influence, ceases to communicate itself between the continuous parts of a magnetizable body, of which one portion is magnetic, and the rest in a neutral state.

Improvements on M. Haldat's method.

In carrying into effect the preceding method of making magnetic figures, a very great difficulty must be experienced in recollecting the invisible traces made by the pole of the magnet, so as to complete a regular figure or drawing. When the figures are made *immediately*, as M. Haldat expressed it, that is, by the actual contact of the pole of the magnet, without any intermediate body, the best method would be to cover the plate of steel with the slightest coating of grease, and sift upon the surface, through a linen bag, some of the finest flour. The pole of the magnet, while tracing the figures on the steel, will remove the flour, and thus exhibit to the eye an accurate picture of what it has traced; and it will thus be easy to make the magnetic figures more distinct by repeating the traces with the magnet. The same thing may be done by putting an etching ground upon the steel plate, and tracing the figure as before. When the figure is completed, the coating of grease and flour, or the etching ground, must be removed previous to the application of the iron filings.

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[1] *Rud. Mag.*, part iii. 61, 62.

Magnetism of Bodies not Ferruginous.

Magnetic figures.

When the figures are to be produced *mediately*, or by the intervention of a non-magnetic substance, such as paper, card, wood, or glass, a fine dust may in like manner be laid upon the surface; but when the interposed substance will receive the mark of a pencil or sharp point, it would be preferable to attach to the cylindrical pole of the tracing magnet a very short point of a non-magnetic substance, which would make a visible mark on the paper, card, or wood, without strewing any fine dust on their surfaces. By the use of such a point, indeed, we may dispense altogether with the interposed substance, and communicate the magnetism by induction to the steel plate, in the very same way as if it had been done by the intervention of a non-magnetic plate whose thickness is equal to the length of the short point or tracer affixed to the pole of the magnet.

The magnetic figures might be rendered permanent by covering the steel plate either with a gummy or balsamic solution, which will indurate by exposure to the air; or with a coating of some easily melted substance, which becomes fixed at ordinary temperatures. If we sift the iron filings on the steel plate when covered with such a fluid, the filings will take their magnetic position round the traced lines, and will become fixed by the induration or solidification of the fluid coating.

CHAP. III.—ON THE MAGNETISM OF BODIES NOT FERRUGINOUS.

SECT. I.—*On the Magnetism of Metals, Minerals, and other Bodies.*

Magnetism of metals, &c., not ferruginous.

Iron was long regarded as the only body endowed with the property of acting and of being acted upon as a magnet; and though other metals and substances have been found to possess the same property, and though all substances whatever were found by Coulomb to obey the power of a strong magnet, yet it is still a matter of doubt whether the magnetic effects thus produced are owing to a magnetism residing in the proper substance of the body, or are owing to a minute quantity of iron which enters into their composition.

Magnetism of nickel.

The most magnetic metal next to iron is *nickel*. It receives and retains communicated magnetism longer than any other metal, and needles of nickel have a distinct polarity. These properties have been found in nickel after it has been repeatedly purified, though some authors have stated that they could not detect this property in certain specimens. A very decisive and instructive experiment on the magnetic qualities of nickel was made by M. Biot.[1] He possessed a needle of nickel which had been purified by M. Thénard. It was 212 millimetres long, six broad, and 5·178 grains in weight. Having made a needle of steel of exactly the same dimensions, and which weighed 4·586 grains, he magnetized them both to saturation, and caused them to oscillate in the magnetic meridian. The nickel needle performed ten oscillations in eighty-seven seconds, and the steel one the same number in forty-five and a half seconds. As the shape of the needles was the same, the momenta of their directive forces were directly as their weights, and inversely as the squares of eighty-seven seconds and forty-five and a half seconds, that is, as 0·3088 to 1, that is, the directive force of the needle of nickel was *nearly one-third* of that of the steel needle. Now it is impossible to suppose that purified nickel could contain such a large proportion of iron as is necessary to produce such a degree of magnetic polarity, without its being easily recognised by the chemist; and M. Biot supposes that the magnetic power of the nickel might have been still further increased by the means which are used to modify the coercive power of steel and iron.

Magnetism of Bodies not Ferruginous.

Brass.

A series of careful experiments were made by M. Cavallo, on the magnetism of *brass* when hammered. He found that brass, whether old or new, British or foreign, was made magnetic when placed between two pieces of card and hammered on an anvil with a common hammer; and that the magnetism thus imparted was always removed by making the brass red hot, and could again be communicated to it. Lest it might be supposed that ferruginous matter might pass to the brass through rents or openings in the card, he hardened a piece of brass by beating it between two large flints, using one piece as a hammer, and the other as an anvil. The hammered brass became magnetic, but not so strongly as before; which arose probably from the rough and irregular surfaces of the flints, which prevented the brass from being hardened as uniformly as it was with the steel hammer. The flints, before and after the experiment, did not possess the slightest magnetism.

The degree of magnetism communicated to brass by hammering is vaguely stated by Cavallo to have been such "as to attract either pole of the needle from about a quarter of an inch distance." The following are the conclusions which M. Cavallo has drawn from these and other experiments:—

"1*st*, That most brass becomes magnetic by hammering, and loses its magnetism by annealing or softening in the fire, or at least its magnetism is so far weakened by it, as afterwards to be only discoverable when set to float on quicksilver.

"2*d*, The acquired magnetism is not owing to particles of iron or steel imparted to the brass by the tools employed, or naturally mixed with the brass.

"3*d*, Those pieces of brass which have that property, retain it without any diminution after a great number of repeated trials, viz., after having been repeatedly hardened and softened.

"4*th*, A large piece of brass has generally a magnetic power somewhat stronger than a smaller piece, and the flat surface of the piece draws the needle more forcibly than the edge or corner of it.

"5*th*, If only one end of a large piece of brass be hammered, then that end alone will disturb the magnetic needle, and not the rest.

"6*th*, The magnetic power which brass acquires by hammering has a certain limit, beyond which it cannot be increased by farther hammering. This limit is various in pieces of brass of different thicknesses, and likewise of different qualities.

"7*th*, Though there are some pieces of brass which have not the power of being rendered magnetic by hammering, yet all the pieces of magnetic brass that I have tried lose their magnetism, so as no longer to affect the needle, by being made red hot, excepting indeed when some pieces of iron are concealed in them, which sometimes occurs; but in this case the piece of brass, after having been made red hot and cooled, will attract the needle more forcibly with one part of its surface than with the rest of it; and hence, by turning the piece of brass about, and presenting every part of it successively to the suspended magnetic needle, one may easily discover in what part of it the iron is lodged.

"8*th*, In the course of my experiments on the magnetism of brass, I have twice observed the following remarkable circumstance:—A piece of brass which had the property of becoming magnetic by hammering, and of losing the magnetism by softening, having been left in the fire till it was partially melted, I found upon trial that it had lost the property of becoming magnetic by hammering; but having

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[1] *Traité de Physique*, tom. iii., p. 126.

Magnetism of Bodies not Ferruginous.

been afterwards fairly fused in a crucible, it thereby acquired the property it had originally, viz., that of becoming magnetic by hammering.

"9*th*, I have likewise often observed, that a long continuance of a fire so strong as to be little short of melting hot, generally diminishes, and sometimes quite destroys, the property of becoming magnetic in brass. At the same time the texture of the metal is considerably altered, becoming what some workmen call *rotten*. From this it appears, that the property of becoming magnetic in brass by hammering, is rather owing to some particular configuration of its parts, than to the admixture of any iron; which is confirmed still farther by observing that Dutch plate brass (which is made, not by melting the copper, but by keeping it in a strong degree of heat whilst surrounded by *lapis calaminaris*) also possesses that property; at least all the pieces of it which I have tried have that property. From these observations it follows, that when brass is to be used for the construction of instruments wherein a magnetic needle is concerned, as dipping needles, variation compasses, &c., &c., the brass should be either left quite soft, or it should be chosen of such a sort as will not be made magnetic by hammering, which sort, however, does not occur very frequently."

These judicious suggestions of M. Cavallo respecting the condition of the brass parts of azimuth compasses were not attended to as they ought, and we have no doubt that various grave errors have arisen from their neglect. Many examples have since occurred in which the errors were detected; and it is now the invariable practice of well-informed instrument-makers to reject hammered brass bowls for compasses, and to use those which are cast and turned for the purpose.

Magnetism of cobalt, zinc, &c.

M. Cavallo and others have observed, that cobalt, zinc, copper, and bismuth, as well as their ores, are attracted by the magnet, and antimony when gently heated. Minerals which are not metallic are almost all acted upon by the magnet, particularly where they have experienced the action of fire. The pure earths, and particularly silex, are found to have the same property. Among minerals, the following table shows those which are attracted and those which are not attracted by the magnet; but we place little faith in their accuracy.

Of gems.

Minerals not attracted.	Minerals attracted.
Diamond.	Oriental ruby.
Pellucid crystals.	Chrysolite.
Amethyst.	Tourmaline.
Topaz.	Emerald.
Calcedony, and other crystals whose colouring matter is expelled by heat.	Garnet.
	Several micas containing iron.

Of mica.

Some accurate experiments were made on mica by M. Biot. The chemical composition and optical structure of different varieties of this mineral vary greatly. M. Biot examined particularly mica from Siberia and mica from Zinwald in Bohemia. Though both were highly pellucid, yet chemical reagents indicated in each the existence of oxide of iron. In the Bohemian mica it was greatest, and, according to an accurate analysis by Vauquelin, amounted to 20 per cent. Before the Siberian mica was analysed, M. Biot tried their magnetic properties. He cut out of each, thin rectangular plates of the same form, which he subdivided into smaller similar pieces, and having united them in a bundle, he suspended each bundle by a silk fibre, and caused each bundle to oscillate in succession between the poles of two strong magnets. The bundle of Zinwald mica performed 12 oscillations in 55 seconds, and that of the Siberian mica only 7 in the same time. Hence the magnetic powers of the two micas were as 6·8 to 20, the ratio of 49 and 14 to the squares of the number of oscillations. If the oxide of iron, then, be the cause of their magnetic virtue, it should exist in the above proportions of 6·8 to 20; and as it was found to be 20 per cent. in the Zinwald mica, it ought to be 6·8 in the Siberian. It is very remarkable that the result of Vauquelin's analysis gave exactly this percentage of the oxide of iron, though it was not known to M. Biot till his experiment had been made.

Magnetism of Bodies not Ferruginous.

Magnetism of combined metals.

The existence of magnetism in brass, while there appeared not the least trace of it either in the copper or zinc of which it is composed, led philosophers to investigate the effects produced by the union of different metals, or by their combination with other substances. *Iron* itself is a simple chemical body. *Steel* is a combination of iron and carbon. The *loadstone* is a combination of iron and oxygen; and as no magnetism was found either in carbon or oxygen, philosophers were naturally led to believe, as M. Pouillet has remarked, that the magnetic fluid resides in the iron, and that it is carried with the atoms of that metal into all the chemical combinations which they form. They therefore expected to find magnetic properties more or less developed in all ferruginous bodies, whether the iron was an accidental or an essential ingredient; and indeed cast iron, plumbago, and the oxides and sulphurets of iron, exert a sensible action on the magnetic needle.

Anti-magnetic bodies.

These views, however, are not in unison with facts which seem to have been well ascertained. Dr Matthew Young found, that the smallest admixture of antimony was capable of destroying the polarity of iron; and M. Seebeck stated, that an alloy of one part of iron and four parts of antimony was so completely destitute of magnetic action, that, even when it was put into rotation, it exerted no power over the magnetic needle. The magnetic qualities of nickel also are destroyed by a mixture with it of other metals. Chenevix found that a very small proportion of arsenic deprived a mass of nickel which had previously exhibited a strong magnetic power, of the whole of its magnetism; and Dr Seebeck found that an alloy of two parts of copper with one of nickel was entirely devoid of magnetism, and on this account he recommended it as well suited for the manufacture of compass boxes. On the other hand, Mr Hatchet ascertained, that when a large proportion of *carbon*, or *sulphur*, or *phosphorus*, was combined with iron, the iron was enabled fully to receive and retain its magnetic properties; but he at the same time found that there was a limit beyond which an excess of any of these three substances rendered the compound wholly incapable of receiving magnetism.

Animal and vegetable substances, after combination, are said to be attracted by the magnet. The flesh, and particularly blood, are acted upon more powerfully than other parts, and bone less powerfully. Burned vegetables have the same property, and also soot and atmospheric dust; and M. Cavallo maintained that brisk chemical effervescence acted upon the magnetic needle.

Sect. II.—*Account of the Experiments of Coulomb, Becquerel, Arago, and Seebeck, on the Existence of Universal Magnetism.*

Universal magnetism.

These various experiments on the magnetic power of so many classes of bodies, differing essentially in their composition, and in many of which it could not be reasonably supposed that iron existed, led some philosophers to believe that almost all substances gave indications of magnetism. M. Cavallo announced this opinion, but Mr Bennet questioned the accuracy of the experiments, and ascribed the movements observed in the needle to the agitation of the air in the receiver, arising from changes of temperature produced by the proximity of the observer's body, or from other causes.

It was not therefore till 1802, that the supposition of

Magnetism of Bodies not Ferruginous.

Coulomb's experiments.

universal magnetism was put to the test of rigorous experiment. The apparatus which Coulomb employed for this purpose is shown in fig. 22, where AA is a glass receiver perforated at its top, and having a tube A′B, with a cork B, which could be raised and lowered with facility. Through this cork passed a rod tt' of wood or metal, to which was attached a silk fibre, which suspended a ring of very fine paper, on which the small needle *ns* (about the third of an inch long and $\frac{1}{50}$th thick) was placed. The receiver was then placed so as to inclose the opposite poles N, S of the powerful magnets M, M, each formed of four bars of steel tempered to a white heat. Each bar was 17 inches long, $\frac{3}{8}$ths of an inch wide, and $\frac{1}{6}$th of an inch thick; each bundle of four bars being $1\frac{3}{8}$th of an inch wide, and $\frac{1}{3}$d of an inch thick. The distance N, S, of their poles was $\frac{8}{10}$ths of an inch. In making the experiments, the rod tt' was turned till the needle *ns* was removed from the influence of the magnets; and after the number of its oscillations was observed, the rod tt' was turned till the needle descended between the poles N, S of the magnets, when the number of oscillations of the needle was again counted, or the time in which a given number of oscillations was performed. If the needle performed the same number of oscillations in the same time, whether it oscillated between the poles N, S, or beyond their influence, it is obvious that the magnets exercised no power over them; but this was never the case, and Coulomb asserted that all substances whatever, when formed into small needles, turned themselves in the direction of the poles N, S, and after a few oscillations, finally settled in that position. When these bodies were moved a very little way out of their position of equilibrium, they immediately began to oscillate round it, the oscillations being always performed more rapidly in the presence of the magnets than when they were removed out of their influence. Gold, silver, glass, wood, and all substances, whether organic or inorganic, thus obeyed the power of the magnets. Hence it was natural to conclude, either that all bodies are susceptible of magnetism, or that they contain minute quantities of iron, or other magnetic metals, which give them that susceptibility. M. Biot did not consider this alternative so inevitable as it appears, and threw out the conjecture, that the action may not be magnetic, but may be owing to some small force similar or analogous to the electrical forces developed by the simple contact of heterogeneous bodies. This no doubt might be, if there was any contact; but, in the absence of any other reasons, such as later experiments have afforded, for ascribing the observed effects to another cause, we cannot but think that it was even then the wiser alternative to give a preference to that opinion which ascribes the phenomenon to the existence in all bodies of a slight susceptibility to magnetic action.

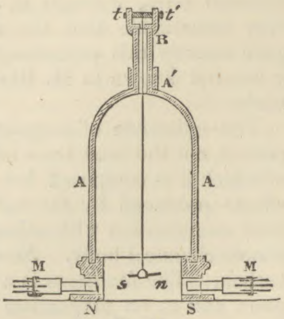

Fig. 22.

The results of experiments made by Coulomb on the comparative magnetic susceptibilities of cylindrical needles of gold, silver, lead, copper, and tin, which had been purified with the greatest care by MM. Sage and Guyton, we have already given in our history of magnetism. M. Coulomb made a number of experiments on the effects experienced by needles of white wax containing different proportions of iron filings, and he came to the conclusion that the intensities of the action which they experienced when oscillating between two magnets, was proportional to the absolute quantities of iron which they contained, the distribution and chemical state of the ferruginous particles being the same.

Magnetism of Bodies not Ferruginous.

Since the time of Coulomb, methods different from his have been employed in developing magnetism in all bodies whatever. In order to detect small quantities of iron in minerals, M. Haüy employed the process of what he calls *double magnetism.* For this purpose he placed a small bar-magnet in the direction of the needle, and in the same horizontal plane, the two similar poles being placed towards each other. The magnet being now brought slowly towards the needle, the latter deviates from the direction of the magnetic meridian, and takes a position perpendicular to it; an effect arising from the combined action of the poles of the magnet and the earth upon the magnetism of the needle. In this position, *a very feeble magnetic action* is sufficient to make the needle turn round and place its south pole opposite the north pole of the needle.

When the magnet is above the plane of the needle, and their opposite poles placed near each other, the needle does not change its direction while the point of suspension is beyond the bar and at a suitable distance; but it is not so when the distance changes, for it tends continually to place itself perpendicular to the line of the poles.

Researches of M. Becquerel.

This important subject was investigated by M. Becquerel, who obtained the following results.[1] His bar-magnet consisted of six united bars, each 8 decimetres long and 2 centimetres broad. The needle was place at different heights within and without the bar, and he sought to determine for each height the horizontal distance from the point of suspension (which is always in the line of the poles) to the nearest extremity of the needle, in order that its direction might be perpendicular to that line. The results were as follows:—

Vertical Distances from the centre of suspension to the Bar. Millimetres.	Horizontal distances of the centre of suspension to the extremity, in order that the needle might take a perpendicular position. Millimetres.
100	60 within.
150	55
200	46
250	23
300	12
350	45 without.
400	82

Hence it appears, that when the centre of suspension is above the bar, the perpendicular position is obtained by increasing the vertical and diminishing the horizontal distance; and that both these distances are increased while the centre of suspension is below the bar; and the direction of the deviation depends on accidental causes, and is often determined by the simple motion of the apparatus.

When M. Becquerel substituted for his magnetic needle a needle of soft iron, the results were exactly the same, differing only in their intensity. We come now to the original part of M. Becquerel's inquiry. Instead of a needle he used a small paper case filled with *deutoxide of iron,* or a mixture of deutoxide and tritoxide. With the former the effects were the same as with the steel needle; but it was different with the latter, in which one part of deutoxide was mixed with thirty parts of tritoxide.

If the centre of suspension be placed as near as possible to the north pole of the bar-magnet, and in the line of the poles, the paper case will take immediately a direction perpendicular to this line, instead of one coincident with it, as a soft-iron needle would have done. If we put it out of this direction, it will return to it by a series of oscillations, whose velocity depends on the quantity of the deutoxide. From this it follows, that *all the south-*

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[1] *Traité Exp. de l'Electricité, &c.,* tom. ii., p. 387.

Magnetism of Bodies not Ferruginous.

polar magnetism of the paper case is situated on the side of it next the bar-magnet, while the north polar magnetism is on the other side, as may be exhibited by carrying a small magnetic needle along the paper case. Such a distribution of magnetism is impossible in soft iron or tempered steel.

If the centre of suspension be above the bar, the paper case will deviate from the position which it had at first, and tend to place itself in the direction of the line of the poles; an effect quite opposite to that produced by a steel or iron needle. The following were the experimental results:—

Vertical Distances of the Centre of Suspension from the Bar.	Horizontal Distances of the same Centre to one of the Extremities of the Bar.	Deviations of the Paper Case from the Direction perpendicular to the Line of the Poles.
10 millimetres	5	24°
	10	44
	15	60
	20	73
	25	78
	30	84
20 millimetres	5	50
	10	65
	15	73
	20	77
	30	32
30 millimetres	5	70
	20	76
	30	82

The *transverse magnetism* acquired by the paper case is permanent for some time, however small may be the proportion of the deutoxide which it contains.

M. Becquerel next filled the paper case with very pure tritoxide, obtained by calcining nitrate of iron. The effect was much weaker than before. When the point of suspension was very near one of the extremities of the bar, the paper case still placed itself in a position perpendicular to the line of the poles; but if this point was placed above or below the bar, changing at the same time the vertical distance, the paper case deviated from its primitive direction, without, however, taking a direction perpendicular to that which it commonly takes when the centre of suspension is very near the extremity. It might be possible, M. Becquerel thinks, to attain the perpendicular direction by employing much stronger magnets. The following were the experimental results:—

Vertical Distances from the Point of Suspension to the Bar.	Horizontal Distances of the same Point from the end of the Bar.	Deviations from the Direction perpendicular to the Line of the Poles.
	Without the Bar.	
5 millimetres	5	25°
	10	34
	15	48
	20	55
	25	70
10 millimetres	5	32
	10	37
	15	43
	20	46
	25	40
	Within the Bar.	
5 millimetres	10	26
	15	—
	20	45
	25	51
10 millimetres	10	20
	15	30
	20	45
	25	50

Whenever the tritoxide contains the smallest quantity of the deutoxide, the velocity of the oscillations increases very powerfully. If, for example, we take *two* paper cases, one filled with tritoxide, and the other with tritoxide mixed with one-thirtieth of the deutoxide, the first will perform twelve oscillations in thirty seconds round a direction perpendicular to the line of the poles, while the other will execute twenty-five in the same time. Hence we may by this means readily determine the quantity of the deutoxide of iron contained in the tritoxide.

Magnetism of Bodies not Ferruginous.

With needles of wood, &c.

M. Becquerel next employed needles of wood, gum-lac, and other substances, which have still a feebler magnetism than the tritoxide of iron. He placed a needle of white wood, *ns*, four centimetres long and two millimetres in diameter, above the interval between the opposite poles of two bar-magnets, as in fig. 22, the distance between N and S being three or four millimetres. The point of suspension was as near as possible to NS. The needle placed itself perpendicular to the line of the poles NS, in place of the position observed by Coulomb coincident with NS. It comports itself therefore like the mixture of deutoxide and tritoxide of iron, or like the tritoxide alone. But if we separate gradually the extremities N, S of the bars, the wooden needle will place itself in the line NS joining the poles, as shown in the figure. The deviations were as follows:—

Distances of N, S.	Deviations of the Wooden Needle from the perpendicular position.
3 or 4 millimetres	0°
10 ...	18
20 ...	36
30 ...	56

When the bars are very close, and the needle in the perpendicular position, if we draw it out of this position, and keep it some instants in the direction of this line, it will remain there; but the smallest motion will cause it to return into its primitive direction, which it takes in preference to any other.

If we use only one bar-magnet, and place the wooden needle precisely opposite one of its poles, and as near as possible to the end of the bar, it will still direct itself perpendicularly to it; but if, while the point of suspension remains always in this line, we advance it within the bar, the needle will deviate from its direction, without, however, reaching the position of 90°, as will be seen from the following results:—

Distances of the Centre of Suspension from the Extremity of the Bar.	Deviations of the Wooden Needle.
5 millimetres	12°
10 ...	18

Beyond ten millimetres the deviations increase insensibly and irregularly, so that they cannot be measured.

General conclusion.

From these interesting experiments, M. Becquerel concludes that the magnetic effects produced by a strong bar-magnet upon a magnetic needle, or one of soft iron, differ essentially from those which take place in all bodies where the magnetism is very weak. In the former, whatever be their positions and directions, the magnetism is always distributed in the direction of their length, to the exclusion of every other direction; whereas in the tritoxide of iron, wood, and gum-lac, it is distributed in a direction which depends on the distance of the body from the poles of the magnet, so that the distribution varies with the direction which the magnet causes these needles to take, in virtue of the action which it exercises over them.

Discoveries of M. Arago.

The universal prevalence of magnetism in all bodies whatever has been established by a beautiful discovery of M. Arago. This distinguished philosopher conceived the idea of studying the oscillations of a magnetic needle when placed above or near any body whatever. Having suspended a magnetic needle above metal, or even water, and caused it to deviate a certain number of degrees from its position, it began, when left to itself, to oscillate in arcs of less amplitude, as if it had been placed in a resisting medium; and, what was peculiarly curious in these experiments, this diminution in the amplitude of the oscillations did not alter the number of oscillations which were performed in a given time. The following were some of M. Arago's

Magnetism of Bodies not Ferruginous.

experiments with *water*, *ice*, and *glass*, the semiamplitude of the oscillations being at the instant 43°.

The distance of the water from the needle was	0·65 millimetres.
The amplitude lost 10° in	30 oscillations.
When the distance was	52·2 millimetres.
A loss of 10° of amplitude required	60 oscillations.

That is, the number of oscillations required to diminish the amplitude 10° was twice as great when the distance of the needle from the water was 52·2 millimetres, as when it was 0·65.

By placing the same needle upon ice M. Arago obtained the following results :—

Distance of the Needle from the Ice. Millimetres.	Diminution of the Amplitude.	Number of Oscillations by which this diminution was effected.
0·70	From 53° to 43°	26 oscillations.
1·26	From 53 to 43	34 ...
30·50	From 53 to 43	56 ...
52·20	From 53 to 43	60 ...

By placing another needle near a plate of crown glass, he obtained the following results :—

Millimetres.		
0·91	From 90° to 41°	122 oscillations.
0·99	From 90 to 41	180 ...
3·04	From 90 to 41	208 ...
4·01	From 90 to 41	221 ...

Plates of metal afforded M. Arago similar results ; but he nevertheless observed that those metals which act with more energy than glass, wood, &c., have a mode of action different from that of these substances. From all these results, it is manifest that all bodies, when placed near a magnetic needle in a state of oscillation, exercise over it an action, the effect of which is to diminish the amplitude of its oscillations, without altering their number ; and hence the doctrine of the universal prevalence of magnetism in all bodies derives a new confirmation.

When Dr Seebeck of Berlin heard of the discovery of M. Arago, he made a magnetic needle two and an eighth inches long oscillate at a distance of three lines above plates of various bodies, and counted the number of oscillations which were required in each case to reduce the amplitude from 45° to 10°.

Substances employed.	Thickness of the Plates.	Number of Oscillations of the Needle.
Marble	— line	116 oscillations.
Mercury	2·0 ...	112 ...
Bismuth	2·0 ...	106 ...
Platina	0·4 ...	94 ...
Antimony	2 0 ...	90 ...
Lead	0·75 ...	89 ...
Gold	0·2 ...	89 ...
Zinc	0·5 ...	71 ...
Tin	1·0 ...	68 ...
Brass	2·0 ...	62 ...
Copper	0·3 ...	62 ...
Silver	0·3 ...	55 ...
Iron	0·4 ...	6 ...

Dr Seebeck found, that in alloying magnetic with non-magnetic substances, he formed *compounds which exercised no action on the magnetic needle.* The alloys which had particularly this singular property were those consisting of four parts of antimony and one of iron, or two parts of copper and one of nickel. In these cases the magnetism of the two ingredients must have been neutralized by their opposite actions.

SECT. III.—*On Diamagnetism.*

The doctrine of universal magnetism, as explained in the two preceding sections, has not stood the test of recent and more profound investigations. The fine researches of Dr Faraday have thrown a new light upon the subject, and brought to view a series of remarkable phenomena of which we shall endeavour to give a brief account.

In the year 1845 Dr Faraday discovered, that when magnetic currents, or, as he expresses it, lines of magnetic force, pass through certain bodies, they communicate to these bodies a certain magnetic condition, which, in transparent bodies, is analogous to rotatory double refraction and polarization, and which in other bodies is the reverse of that which takes place on iron, nickel, and some other metals.

Magnetism of Bodies not Ferruginous.

If a parallelopiped, NS*ns*, of heavy flint glass, 2 inches square and $\frac{1}{2}$ an inch thick, and having no action on polarized light, is placed, as in the figure, on the poles N, S, of a powerful electro-magnet NCS, and a strong galvanic current passed through it in the direction of *sn*, the glass will neither be attracted nor repelled, but is found to have received, while the current is passing through it, such a structure, resembling that of quartz and certain fluids, as to *turn the plane of a polarized ray* in the same direction as the current. If the polarized ray is transmitted through the upper and under faces G, H, no effect whatever is produced. The rotation of the plane of polarization is from *left to right* when the ray enters the face *s*N and the observer looks into the face *n*S, and from *right to left* when the ray enters *n*S and the observer looks into *s*N. This is a very remarkable fact, as the direction of rotation is the same in rock-crystal and other bodies through whatever side the light enters.

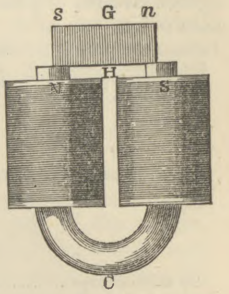

Fig. 23.

The intensity of the rotatory force depends upon the strength of the galvanic current, and upon the length of the piece of glass. When the ray, by reflections at *n* and *s*, was made to pass *three* or *five* times through the length *ns* of the glass, the effect was increased *three* or *five* times, just as in rock-crystal it is increased by increasing the thickness of the plate.

M. Bertin found that this electro-magnetical polarization as it has been called, or magne-crystallization as Dr Tyndall calls it, as produced in *boro-silicate of lead* (Faraday's flint glass), and the *sulphuret of carbon*, does not vary in intensity, by a variation, within very considerable limits, of the electro-magnetic force. He found that the most energetic of the fluids which exhibited the rotatory structure were *bichloride of tin, sulphuret of carbon, olive oil, alcohol,* and *water ;* the sulphuret of carbon having *three* times the force of water.

In studying this subject, M. Matthiessen of Altona obtained the following results :—

1. The rotatory force diminished as the distance of the poles N, S was increased, the diminution being more rapid when the glass was thinner.

2. The effect was not a maximum when the glass was in absolute contact with the poles of the magnet ; the magnetism probably passing freely through the glass without producing rotation.

3. When the parallelopiped *ns*NS consisted of six similar plates, the effect was diminished about $\frac{2}{13}$ths, but there was no diminution when the plates were cemented by Canada balsam.

4. With 50 elements of Bunsen's pile, producing such a degree of magnetism that one of the vertical poles of the magnet raised 25 kilogrammes, M. Matthiessen obtained the following results :—

	Thickness in Millimetres.	Angle of Rotation.
Silicate seplombique	15	20
Silicate quadroplombique	10	18
Silico-aluminate of lead	10	16
Borate triplombique	17	16
Red realgar	12	11
Borate of bismuth	14	11
Borate of lead, neutral	24	10

Magnetism of Bodies not Ferruginous.

	Thickness in Millimetres.	Angle of Rotation.
Silicate of lead, neutral	30	10
Glass of antimony	27	9
Borosilicate of lead	26	9
Rock-salt	26	6

From a series of interesting experiments, M. Bertin recently obtained the following values of the rotatory force, which he calls the *coefficients of magnetic polarization.* In all the experiments, the thickness of the body and the distance of the poles of the magnet were the same:—

	Coefficient.
Faraday's flint-glass	1·00
Guinand's do.	0·87
Matthiessen's do	0·83
Common do.	0·53
Bichloride of tin	0·77
Sulphuret of carbon	0 74
Protochloride of phosphorus	0·51
Chloride of zinc, dissolved	0·55
Chloride of calcium, dissolved	0·45
Water	0·25
Alcohol, ordinary, of 36 Beaumé	0·18
Ether	0·15

The remarkable property of magnetic polarization will, no doubt, be found in many other bodies both solid and fluid; but it has not yet been detected in Iceland spar, rock-crystal, or any doubly-refracting substances. It will be found doubtless in diamond, garnet, and other minerals that do not possess double refraction.

But though a crystalline structure is not produced in doubly-refracting bodies, they are influenced by the magnetic current in a different way, like a large class of bodies to which the name of diamagnetic has been given.

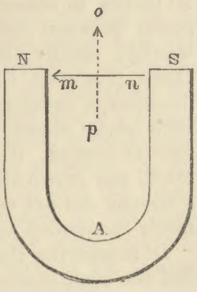

Fig. 24.

If N, S are the poles of a very powerful electro-magnet NAS, and if bodies such as those examined by Coulomb are placed between these poles, they will take the position *mn;* but there is another class of bodies, such as bismuth, which if placed in the *magnetic field* NS, will not place themselves *axially* like *mn*, but equatorially like *op*, even though they had previously the position *mn.* If the diamagnetic body is nearer N than S, or nearer S than N, that is, out of the centre C, then on pointing equatorially it is apparently repelled, and this, too, by both poles; so that it was inferred by Dr Faraday we have here magnetic repulsion with *polarity* or *directive power.*

Among the numerous diamagnetic bodies which take the equatorial position *op*, we find *wood, animal fibre,* and common vegetable matter; and it has been remarked by Sir W. Harris, "that if a man could be suspended with sufficient delicacy in the magnetic field between the poles of a powerful magnet, he would point equatorially (like *op*) and be repelled by both poles; for all the substances constituting the human frame have this property."

The following is a list of metals which, according to Dr Faraday, when placed in the magnetic field NS, take the *axial* position *mn*:—

Magnetic Metals.
Iron
Nickel
Cobalt
Manganese
Chromium

Magnetic Metals.
Cerium
Titanium
Palladium
Platinum
Osmium.

The following is a list of metals which, according to Dr Faraday, when placed in the magnetic field, take the *equatorial* position *op*:—

Diamagnetic Metals.
Bismuth
Antimony
Zinc
Tin
Cadmium
Sodium

Diamagnetic Metals.
Mercury
Lead
Silver
Copper
Gold

Diamagnetic Metals.
Arsenic
Uranium
Rhodium
Iridium
Tungsten.

The repulsion of bismuth and antimony was observed in 1778 by Brugmans, by M. Lebaillif in 1827, and by other philosophers; but these observations do not affect the entire originality of Dr Faraday's discoveries. M. Becquerel, who noticed the equatorial position of certain substances, supposed it to be the result of ordinary magnetic action, the bodies being magnetized transversely, or across their length, an explanation entirely disproved by the researches of Dr Faraday, which established the existence of a new magnetic condition of matter hitherto unsuspected.

This subject has been treated with great ability by Professor Tyndall, in the *Philosophical Transactions* for 1854 and 1856. Professor W. Weber, in opposition to the received opinion that metals such as bismuth had no polarity or directive power, had proved experimentally the existence of a reverse polarity in diamagnetic bodies. M. von Feilitzsch denied the validity of this inference, and ascribed the observed effect to ordinary induction. By means of an apparatus constructed by Professor Weber, Professor Tyndall has, by aid of able experiments, completely established the doctrine of a duality of action, that is, of a repulsive and a directive power residing in diamagnetic bodies.

In submitting to experiment liquid magnets, or liquid diamagnets (metallic solutions), Professor Tyndall has clearly shown that the former exhibit a polar action the reverse of that exhibited by the latter; and in a subsequent paper[1] he has pointed out the relation of diamagnetic polarity to magnecrystallic action.

Development of Magnetism in all Bodies by Rotation.

CHAP. IV.—ON THE DEVELOPMENT OF MAGNETISM IN ALL BODIES BY ROTATION.

M. Arago's experiments.

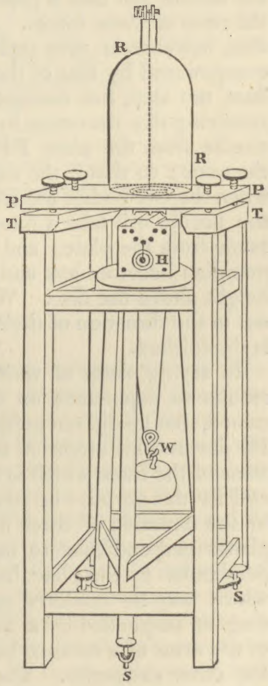

Fig. 25.

When M. Arago was engaged in the experiments described in the preceding chapter, the idea occurred to him of trying if the magnetic needle would be dragged along by the rotatory plates which had the power of diminishing the amplitude of its oscillation. This happy conjecture was immediately confirmed by experiment, and one of the most beautiful discoveries added to the science of magnetism.

The apparatus which he used for this purpose is shown in fig. 25, where H is a clock made of copper, with the exception of two or three pivots, which are of steel. It is supported on a tripod stand, which can be levelled by screws S, S, at the end of its three feet; and the object of it is to give a rapid rotatory motion by a vertical axis, on which is fitted a piece *abc*, fig. 26, with three branches, upon which the revolving discs are to be placed. These discs are perforated at their centre by a small hole which receives the prolongation of the axis of rotation, and they are kept upon the branches *a*, *b*, *c*, by the pressure of a

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[1] *Philosophical Magazine,* February 7, 1856.

Development of Magnetism in all Bodies by Rotation.

screw. Wings *w*, *w*, *w* (fig. 26), which can be inclined at any angle, are applied for the purpose of retarding the velocity of the discs. A plate PP, with an opening in its centre a little larger than the diameter of the discs, rests upon the table TT; and a sheet of paper *ff*, shown in fig. 27 (which is an enlarged view of that part of the apparatus), is pasted to the lower face of PP.

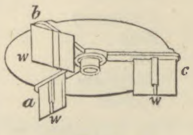

Fig. 26.

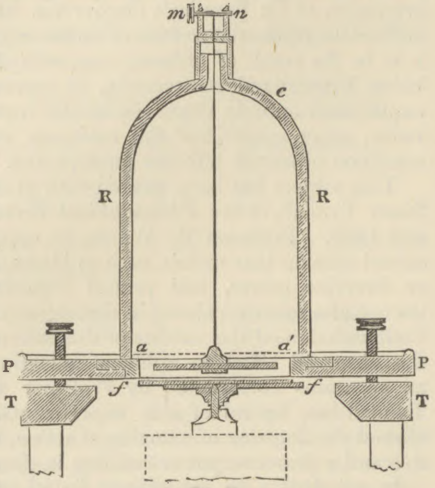

Fig. 27.

A glass receiver RR rests upon the upper face of PP, and within it is suspended the magnetic needle *aa'*, by a fibre of silk attached to the axis and button *mn*, by which the needle can be raised or depressed. A weight W gives motion to the clock, and a hand indicates upon the dial-plate the number of revolutions performed by the disc in a given time.

When a disc of copper was placed on the support *abc*, fig. 26, as shown at PP, fig. 27, and the copper made to revolve beneath the needle *aa'*, with the sheet of paper *ff* intervening, the needle *aa'* is drawn out of the magnetic meridian the instant that the copper begins to revolve, and with a degree of force proportional to the velocity of rotation. As the force with which the needle is dragged from its place is opposed to the magnetic action of the earth, which tends to keep the needle in the magnetic meridian, the needle will take a position of equilibrium depending on the ratio of these forces. When the motion of the copper disc, however, is very rapid, the magnetism of the earth is overpowered by that of the revolving plate, and the needle does not stop, but continues to turn. The action of the revolving disc decreases in proportion as the distance of the needle from the plate PP is increased, the velocity being the same; so that if the motion of the needle be continuous when the two bodies are separated only by a sheet of paper, the needle will take a fixed position by increasing its distance from the plate; and its deviation from the magnetic meridian becomes less and less as it is removed to a greater height above the disc. When the plates have portions cut out in the direction of their radii, their action on the needle is diminished.

In trying plates of various metals, M. Arago found the results so dependent on the alloy which the metals contained, that he did not publish the results which he obtained. He devoted his attention to the determination of the directions of the force which is developed in the revolving discs, and for this purpose he sought the components of this force in the direction of three lines parallel to three co-ordinate planes perpendicular to each other. The *component* perpendicular to the plate he found to be a repulsive force, which may be rendered sensible by means of a very long magnet suspended by a thread vertically to the extremity of the arms of a balance kept in equilibrium by a weight at the other extremity. The moment that the plate begins to revolve, the magnet is repelled, and the beam of the balance inclines to the other side. The *second* component is horizontal and perpendicular to a vertical plane which contains the radius abutting against the projection of the pole of the needle. This is the force which gives a motion of rotation to the needle, and it acts in the direction of a tangent to the circle. The *third* component is parallel to the radius which abuts against the projection of the pole of the needle. It may be determined with a dipping needle placed vertically, so that its axis of rotation is continued in a plane perpendicular to one of the radii of the disc. A similar needle placed at the centre of the disc experiences no action. There is also a second point, nearer the margin than the centre, where a needle experiences no change in its position; but between these points the lower pole is constantly attracted towards the centre, while it is repelled beyond that point.

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Experiments of Messrs Babbage and Herschel.

No sooner were M. Arago's experiments announced to the Institute, which was done at the sitting of the 7th March 1825, than philosophers in every part of Europe repeated them, and succeeded in adding several important facts to those discovered by M. Arago. MM. Babbage, Herschel, Barlow, Nobili, Baccelli, Christie, and MM. Prevost and Colladon, took a prominent part in these researches. The results obtained by Messrs Babbage and Herschel were the most important, and the experiments were made in a manner different from those of M. Arago. A horse-shoe magnet, which lifted twenty pounds, was made to revolve rapidly round its axis of symmetry, placed vertically, with its poles uppermost. A circular disc of copper, 6 inches in diameter and $\frac{1}{20}$th of an inch thick, was suspended above the revolving magnet. As soon as the rotation of the magnet commenced, the copper began to turn in the same direction, at first slowly, but afterwards with an increasing velocity. When the magnet was made to turn in the opposite direction, the disc of copper changed the direction of its motion also, and exhibited the same phenomena. Metallic plates, 10 inches in diameter and half an inch thick, when interposed between the magnet and the copper disc, did not sensibly modify the results, as M. Arago had observed. Glass produced no effect, but a sheet of tin-plate iron diminished greatly the influence of the magnet, while two such plates almost destroyed it. They also found that a disc of copper, 10 inches in diameter, and half an inch thick, and revolving with a velocity of seven revolutions in a second, did not communicate any motion to a similar disc freely suspended above it.

In comparing the influence of different metals, each disc had the same diameter and the same velocity; and the following were the results which were obtained by this and another method of observation:—

	Ratio of the Force to that of Copper.	Ratio by another Method.
Copper	1·00	1·00
Zinc	0·90	1·11
Tin	0·47	0·51
Lead	0·25	0·25
Antimony	0·11	0·01
Mercury	0·00	0·00
Bismuth	0·01	0·00
Wood	0·00	0·00

The second method of observation by which the results in the last column were obtained was more expeditious than the first. Portions of different bodies of the same form and dimensions were suspended above a revolving magnet, and the time of successive oscillations and the points of equilibrium were observed.

Our authors next sought to determine the effect produced by a solution of continuity in the metallic disc upon which the revolving magnet acted. For this purpose a disc of lead, 12 inches in diameter and $\frac{1}{10}$th of an inch thick was suspended at a given distance from a horse-shoe magnet revolving with the ordinary rapidity, first in its entire state, and afterwards in the state shown in figs. 28, 29, 30, 31, 32; the black lines in the direction of the radii being the planes where the lead was cut through. The accelerating forces

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represented by $\frac{s}{t^2}$, where s is the number of the revolutions, and t the time employed, are as follow:—

Uncut Disc.	Disc as in fig. 28.	Disc fig. 29.	Disc fig. 30.	Disc fig. 31.	Disc fig. 32.
1258	1047	913	564	432	324

Effects similar, but differing in degree, were obtained with other metals. With soft tinned iron the cutting produced a very slight diminution of effect, whilst in copper the same operation reduced the accelerating force in the ratio of five to one.

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Messrs Babbage and Herschel next tried the effect of filling up the cuts with other metals. A light copper disc, suspended at a given distance above a revolving magnet, performed six revolutions in 54·8. When it was cut, as in fig. 32, its magnetic action was so weakened that it took 121·3 to perform six revolutions. When the eight open radial spaces were filled up with tin, its magnetic action was restored to such a degree that it made six revolutions in 57·3. This fact is very interesting, as tin has less than half the energy of copper. The following results were obtained from other experiments, the numbers representing the accelerating forces or the magnetic energies developed in the plates:—

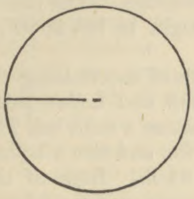

Fig. 28.

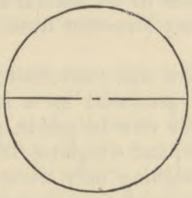

Fig. 29.

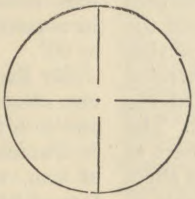

Fig. 30.

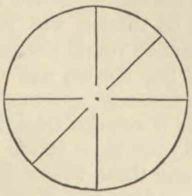

Fig. 31.

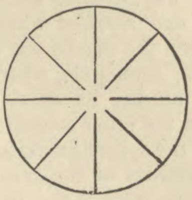

Fig. 32.

Brass not cut	1·00
Brass cut	0·24
Brass soldered with bismuth	0·53
Brass soldered with tin	0·88
Copper not cut	1·00
Copper cut	0·20
Copper soldered with tin	0·91

Law of the force.

In determining the law of the force in relation to the distance, Messrs Babbage and Herschel found it to vary between the ratio of the square and the cube of the distance. Mr Christie found, that when the revolving disc was thick and the needle delicate, the force which produced the deviation of the needle increased directly as the velocity of rotation, and inversely as the fourth power of the distance. MM. Prevost and Colladon found that the angles of deviation, and not their sines, increased in the direct ratio of the velocity, at least within certain limits; and that the sines of the angles of deviation were in the inverse ratio of the two and a half power of the distance.[1]

Experiments of M. Haldat;

M. Haldat made some interesting experiments on this subject. He found that every needle, however weak was its magnetism, obeyed the action of the revolving disc; but that this action disappeared entirely when its polarity disappeared. He found it impossible to magnetize needles by the action of the revolving disc, however rapid; and ascribing this effect to the want of coercive power, he employed discs of iron and steel, both soft and hardened.

A disc of soft iron acted with more energy than one of copper, and with the same velocity it dragged the needle twice the distance that a disc of brass did. Iron strongly hammered acted like soft iron, and was unable to give polarity to a steel needle. But a disc of untempered steel $\frac{1}{25}$th of an inch thick did not produce any appreciable effect on the magnetic needle, which, after a few irregular oscillations, maintained its ordinary position of equilibrium. Hence M. Haldat concluded that the force which acted upon it was in the inverse ratio of the coercive force. He also found that discs in a state of incandescence exercised the same action as those at the ordinary temperature.

of Mr Barlow.

We have already seen, in our historical detail, that about six months previous to the announcement of M. Arago's discoveries, M. Barlow had announced to the Royal Society of London the result of a series of experiments on the magnetic effects produced by iron in rotation. Having found that an iron ball performing 640 revolutions in a minute caused a magnetic needle to deviate several degrees, and to take a fixed position during the continuance of the motion; that the needle deviated in an opposite direction when the motion of the ball was reversed; that there were certain positions in which a bomb 12 inches in diameter, moved by a steam-engine, occasioned no deviation in the needle; that in some positions the deviation was in one direction, and in other positions in another; and that the deviation varied between 0° and 80°; he constructed a regular apparatus for determining the laws of these phenomena, and in which the iron which formed part of it should not influence the results. This apparatus is shown in fig. 33, where S is an iron sphere, made to revolve on a horizontal axis AB, by means of two wheels, like an electrical machine, their diameters being as six to one, so as to perform 720 revolutions in a minute. A table LM was placed near the sphere, for holding the needle, so that the needle could be placed in any position, either above or below the sphere. The table LM being brought to the height of the axis AB, the needle was placed successively in different positions round the sphere. The influence of the earth's magnetism on the needle being destroyed or neutralized by the action of a magnet properly placed for this purpose, and shown at NS standing vertically, Mr Barlow found, that whatever was the azimuth of the needle, its *north pole* approached the sphere S when the upper part of the sphere was moving *towards* the needle, and that its *south pole* ap-

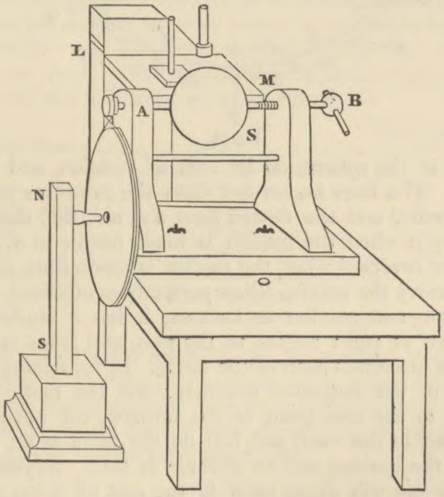

Fig. 33.

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[1] *Bibl. Univers.*, tome xxix., p. 316.

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proached the sphere when the upper part moved *from* the needle.

Having placed the axis of rotation sometimes in the magnetic meridian, sometimes in the direction of east and west, and sometimes in intermediate positions, he found, that whatever was the direction of the axis of rotation, the needle being always a tangent to the sphere, the *north* end of the needle was *attracted* when the sphere moved *towards* the needle, and *repelled* when its motion was *from* the needle. When the needle was carried round the revolving sphere in the semicircle, where the motion was directed towards the needle, its *north* extremity *approached* the sphere, and in the other semicircle it *receded* from it. The points where the sphere exercised upon it no action were at the two extremities of the axis, and those where the effect was a maximum were at the two extremities of an axis at right angles to this. In this case the direction of the needle was towards the centre of the ball.

The different positions of the needle are shown in fig. 34, where *s* is the sphere, *ab* its axis of rotation, and *cd* its equator. The lines *ns*, *ns*, &c., show the primitive position of the needle, and the dotted lines *n's'*, *n's'*, &c., those assumed by it when the motion is made from *c* to *d*. The effects are reversed when the motion is made from *d* to *c*.

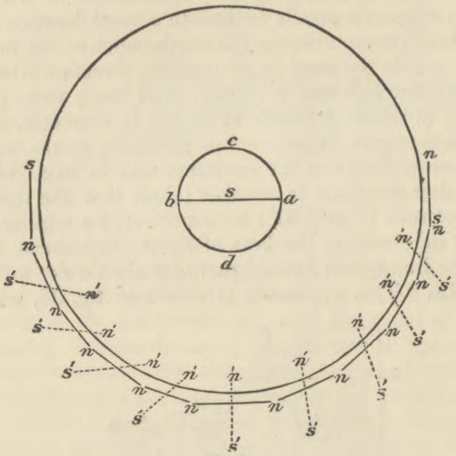

Fig. 34.

If we carry the needle, when perfectly neutralized, round the sphere, and parallel to its axis, it has a tendency to place itself at right angles to the axis, and takes opposite directions at certain parts of the circle. If, for example, the axis be in the magnetic meridian, and the motion from the west to the east point of the horizon, the needle will direct itself to the west, and will do the same at all points between the horizon and an altitude of 60°. Beyond this the north end will direct itself to the east till it has passed the zenith 30° to the west; and then from this point to the west horizon, the north extremity will direct itself to the west; and similar changes will take place under the sphere. The same effects are produced whatever be the direction of the axis and that of motion.

When a magnetic needle *not neutralized* is placed in different positions round the sphere whose axis is in the magnetic direction, the effects produced are as shown in fig. 35, where AB is the axis of rotation, the black lines representing the natural deviations of the needle, and the dotted ones those which it assumes when the sphere is in motion. Beginning at the point A, if the motion be from left to right, that is, from west to east, the needle moves from *n* to *n'* in the same direction till it arrives at 30°. It then remains in its natural direction. The needle moves in a contrary direction from right to left at 60°, 75°, and at 90°.

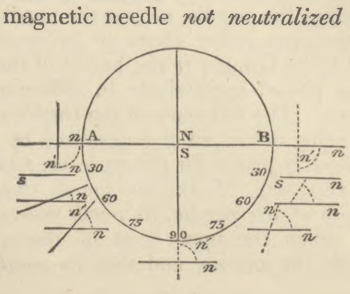

Fig. 35.

Effects of a hollow ball.

Mr Barlow was next desirous of ascertaining the different effects produced by a solid and hollow ball of iron, and with this view he put in motion a solid ball 7·87 inches in diameter, and weighing 68 lb., and also a hollow sphere of iron, weighing only about 34 lb. Both of them performed 640 revolutions in a minute, and the following were the average results:—

			Weight.
Mean deviation of the solid ball	28°	24′	68 lb.
Mean deviation of the hollow ball	15	5	34

When the two balls were at rest, the difference of their action was nothing.

Experiments of Mr Christie.

Mr Barlow's paper on rotation was communicated to the Royal Society on the 14th April 1825, and on the 20th Mr Christie communicated one *On the Magnetism of Iron arising from its Rotation.* Mr Christie's experiments were made with circular plates of iron put in motion by an ingenious piece of machinery, by which he could make the plate revolve in every possible plane in reference to the magnetic meridian. From a great body of well-devised experiments, he obtained the following general law of the deviation due to rotation, so that the direction of the rotation being given, he could tell the direction of the deviation. This law we must give in his own words:—

"I refer the deviations of the horizontal needle to the deviations of magnetic particles in the direction of the dip, or to those of a dipping needle passing through its centre; so that, in whatever direction this imaginary dipping needle would deviate by the action of the iron, the horizontal needle would deviate in such manner as to be in the same vertical plane with it; thus, when the north end of the horizontal needle deviates towards the west, and consequently the south end towards the east, I consider that it has obeyed the deviation of the axis of the imaginary dipping needle, whose northern extremity has deviated towards the west, and its southern towards the east; so that the western side of the equator of this dipping needle has deviated towards the south pole of the sphere, and its eastern side towards the north pole. It would follow from this, that if the north and south sides of the equator of the dipping needle (referring to these points in the horizon) deviated towards the poles, no corresponding deviations would be observed in the horizontal needle; the effect, in this case, taking place in the meridian, would only be observable in the angle which the dipping needle made with the horizon. As it is not my intention at present to advance any hypothesis on the subject, I wish this to be considered only as a method of connecting all the phenomena under one general view. Assuming it, then, for this purpose, it will be found that the *deviations of the horizontal needle due to rotation* are always such as would be produced *by the sides of the equator of this imaginary dipping needle deviating in directions contrary to the directions in which the edges of the plate move,* that edge of the plate nearest to either edge of the equator producing the greatest effect on it."

From another set of experiments, Mr Christie also found that the effect produced on the iron by its rotation is permanent so long as the plate remains stationary; that it is independent of friction; that it is so far independent of velocity, *that the iron can scarcely be moved so slowly that*

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the whole effect shall not be produced; and that the whole effect is produced by making it perform one-fourth of a revolution. After Mr Christie had discovered these peculiar effects, he exhibited some of the phenomena to Mr Barlow, who conceived that the effect would be increased by rapid rotation, and who was thus led to make the experiments of which we have already given an account; but the phenomena differ essentially from those observed by Mr Christie; the former being temporary and dependent on velocity, while the latter are permanent, and independent of the rapidity of rotation.

In comparing the magnetic forces produced by rapid and slow rotation, Mr Christie found that the forces exerted on the needle during the rapid rotation of the plate are always in the same direction as the forces which are derived from the slowest rotation, and which continue to act after the rotation has ceased; but that the former forces are greater than the latter. From a mean of all the observations, the forces seem to be in the ratio of seventeen to thirteen, or very nearly of three to two. Hence Mr Christie conceives that the polarizing of the iron in the same direction will account for the phenomena in both cases; but that the intensity of the polarity during the rapid rotation is greater than of that which appears to be permanent after the rotation, whether slow or rapid, has ceased; and that the phenomena observed during rapid rotation are such as should be expected from what have been described as arising from rotation, without regard to its velocity.

Experiments of Mr Snow Harris.

We have already seen that Messrs Babbage and Herschel interposed plates of various metals between the revolving magnet and the copper disc, and found no perceptible effect to be produced. Mr S. Harris,[1] however, has more recently shown that several substances not supposed to contain iron have the power of intercepting the influence of a revolving magnet. A circular magnetic disc being delicately balanced on a fine central point by means of a rim of lead, was put into a state of rotation on a small agate cup, at the rate of 600 revolutions in a minute; and a light ring of tinned iron, also finely balanced on a central pivot, was placed immediately over it, at about 4 inches distance, by means of a thin plate of glass, on which its pivot rested. When the ring of tinned iron began to move slowly on its pivot by the influence of the magnet revolving below, a large mass of *copper*, about *three* inches thick, and consisting of plates a foot square, was carefully interposed between the magnet and the iron ring. The interposition of the copper soon sensibly diminished the motion of the iron disc, and at length *arrested it altogether.* On again withdrawing the copper, the motion of the disc was restored; and the same effects were repeatedly obtained. In this experiment both the magnet and the disc were inclosed by glass shades, and supported on a firm base.

The same effects were produced by a mass of silver and zinc; but when their thickness was considerably diminished by removing the central plates, the motion of the disc was not impeded. A very great thickness of *lead* was necessary to stop the disc, in consequence, as Mr Harris supposes, of its magnetic energy being so much less than that of copper.

CHAP. V.—ON THE INFLUENCE OF HEAT ON MAGNETISM.

Influence of heat on magnetism.

This interesting department of magnetism divides itself into three parts: 1*st*, On the effect of heat on the development of free magnetism; 2*dly*, On the anomalous attraction observed during the bright red and red heats; and, 3*dly*, On the effect of heat on the distribution of magnetism in magnets.

SECT. I.—*On the Effect of Heat on the Development of Magnetism in Cast and Malleable Iron.*

In cast and malleable iron.

In the course of his experiments on the relative magnetic powers of different kinds of iron and steel, already given in the history of magnetism, Mr Barlow was led to the conclusion that the harder the metal was, the less it exhibited of a magnetic quality: a result which was highly favourable to the hypothesis, that the cohesive power of hardened steel not only prevented the entire development of its magnetism, but also the re-combination of the two kinds of magnetism when they were displaced by the action of a powerful magnet. With the view of establishing this hypothesis, Mr Barlow found it necessary to ascertain whether these different kinds of iron and steel would exhibit the same magnetic powers when reduced to the same degree of softness, which could only be done by heating them in a furnace, and trying their magnetic qualities in that state.

Having procured a bar of soft iron 25 inches long and 1¼ square, and a cast-iron one of nearly the same dimensions, he inclined the bars in the direction of the dip; and having placed a magnetic needle nearly on a level with the upper extremity, and at the distance of 6 inches from it, he observed the deviations produced by the bars in different states of heat. Thus,—

		Mean deviation.	
Cast iron	Cold	21°	30′
Ditto	White heat	0	0
Ditto	Blood-red heat	62	0
Malleable iron	Cold	40	0
Ditto	White heat	0	0
Ditto	Blood-red heat	55	0

These experiments were often repeated with the same results. It deserves to be remarked as a singular result, that cast iron is decidedly inferior in its action when cold, and when hot possesses a superior power to malleable iron.

Mr Barlow now compared malleable iron with soft and hard shear steel. The bars were 24 inches long and 1¼ square, and the following were the results:—

		Mean deviation.	
Malleable iron	Cold	15°	10′
Ditto	White heat	0	0
Ditto	Blood-red	41	11
Soft shear steel	Cold	11	0
Ditto	White heat	0	0
Ditto	Blood-red	48	0
Hard shear steel	Cold	8	0
Ditto	White heat	0	0
Ditto	Blood-red	47	30

These experiments establish the curious fact of the total destruction of the magnetic virtue by a *white heat;* and also the no less important one, that every kind of iron or steel has a greater capacity for developing its magnetism when softened by fire than when cold.

SECT. II.—*On the Anomalous Attraction observed in Cast and Malleable Iron during the Bright Red and Red Heats.*

Anomalous attraction of iron at a red heat.

In pursuing the preceding researches, Mr Barlow was led to observe a remarkable anomaly in the action of the iron at the red heat. When iron brought to a white heat has wholly lost its power, it again acquires, as it passes into the bright red and red, a magnetic power; but what is truly strange, its power is *attractive* for the south end of the needle; that is, if the *north* pole of the needle was attracted when the iron was cold, the *south* end will be attracted when the iron is at a bright red heat.

In order to investigate this subject thoroughly, Mr Barlow made a very extensive series of experiments with four

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[1] *Phil. Trans.*, 1831, p. 497.

Influence of Heat on Magnetism.

different bars, each 25 inches long and 1¼ square, two of them being of cast, and two of malleable iron. He used also other two bars, one of cast and one of malleable iron, of the same dimensions, which were kept as standards to determine the quantity of cold attraction. The time employed in each experiment was a quarter of an hour: the white heat generally continued about *three* minutes when the negative attraction commenced. This attraction lasted about *two* minutes more, when the usual attraction began. This sometimes reached its maximum with great rapidity, but at other times it increased very gradually. The following table contains the results of Mr Barlow's experiments. The letters CB denote the cast-iron bar, and MB the malleable-iron bar; and the sign + indicates when the ordinary attraction of the iron takes place; and − the anomalous or negative attraction.

Influence of Heat on Magnetism.

Table of the Results of Mr Barlow's Experiments on the Effect of Iron on the Compass Needle at different Degrees of Heat.

N.B.—We have omitted the column for white heat, as no effect is ever produced at that temperature.

No.	Description of Bar.	Height and Depth of Centre of Bar from Needle.	Distance of Bar from Needle.	Position of Needle.	Effect when Cold.	Effect of Red Heat.	Effect at Blood-red Heat.	Remarks.
		Inches.	Inches.					
1	C. B. No. 1	0·0	6·0	S. 80° W.	+ 0° 0′	− 17° 0′	0° 0′	South end drawn to the bar at red heat.
2	M. B. No. 2	4·5 below	6·0	Ditto	+ 30 0	0 0	+ 45 0	
3	C. B. No. 2	Ditto	6·0	Ditto	+ 18 0	0 0	+ 49 0	
4	M. B. No. 1	Ditto	6·0	Ditto	+ 29 30	− 12 0	+ 44 0	
5	Ditto	1·3 below	6·0	Ditto	Not observed	0 0	+ 52 0	
6	Ditto	4·5 below	6·0	N. 80 W.	Ditto	− 12 30	+ 70 0	This bar being left standing, it attracted the same three days after.
7	Ditto	Ditto	6·0	S. 80 W.	Ditto	− 12 30	+ 30 0	The needle suspected to touch the box.
8	Ditto	Ditto	6·0	Ditto	Ditto	0 0	+ 25 0	
9	Ditto	Ditto	6·0	Ditto	Ditto	− 19 0	+ 30 0	
10	Ditto	1·0 above	6·0	Ditto	Ditto	− 15 0	+ 4 0	
11	M. B. No. 2	12·5 below	8·5	N. 80 W.	+ 29 30	0 0	+ 37 30	Observed at the same time with two compasses.
12	Ditto	Ditto	8·5	N. 80 E.	+ 30 0	0 0	+ 41 0	
13	C. B. No. 1	Ditto	8·5	N. 80 W.	+ 16 0	0 0	+ 42 30	Ditto ditto.
14	Ditto	Ditto	8·5	N. 80 E.	+ 15 30	0 0	+ 47 30	
15	M. B. No. 2	9·0 below	8·5	N. 80 W.	+ 28 30	− 1 0	+ 39 30	Ditto ditto.
16	Ditto	Ditto	8·5	N. 80 E.	+ 29 30	− 1 30	+ 42 0	
17	C. B. No. 1	Ditto	8·5	N. 80 W.	+ 15 45	− 1 30	+ 45 0	Ditto ditto.
18	Ditto	Ditto	8·5	N. 80 E.	+ 16 0	− 1 30	+ 49 0	
19	M. B. No. 2	6·0 below	8·5	N. 80 W.	+ 25 0	− 3 0	+ 32 30	Ditto ditto.
20	Ditto	Ditto	8·5	N. 80 E.	+ 26 0	− 3 30	+ 33 0	
21	C. B. No. 1	Ditto	8·5	N. 80 W.	+ 11 30	− 3 30	+ 36 30	Ditto ditto.
22	Ditto	Ditto	8·5	N. 80 E.	+ 13 0	Not observed	+ 36 30	
23	M. B. No. 2	3·0 below	6·0	S. 80 E.	+ 8 0	− 21 30	Not observed	Ditto ditto.
24	Ditto	Ditto	6·0	N. 45 W.	Not observed	− 25 30	+ 25 30	
25	M. B. No. 1	0·0	6·0	Ditto	0 0	− 40 0	0 0	North end drawn to the bar at red heat.
26	M. B. No. 2	1·0 above	5·3	N. 60 W.	+ 2 0	− 4 30	+ 5 30	Both attractions very gradual.
27	M. B. No. 1	Ditto	5·3	Ditto	Not observed	− 12 30	+ 5 30	Passed suddenly to 12½°, but returned immediately.
28	M. B. No. 2	9·0 above	6·0	N. 85 E.	+ 47 30	− 2 30	+ 60 0	Attractions gradual.
29	M. B. No. 1	Ditto	6·0	Ditto	+ 47 30	− 2 30	+ 60 0	Ditto.
30	M. B. No. 2	1·0 below	5·5	N. 45 W.	Not observed	− 55 0	+ 5 45	Negative attraction rather sudden.
31	M. B. No. 1	4·5 above	7·0	N. 75 E.	Ditto	− 2 30	+ 33 30	Motion of needle very slow.
32	M. B. No. 2	1·7 below	5·5	N. 45 W.	Ditto	+ 100 0	+ 13 30	100° very sudden, returned immediately.
33	M. B. No. 1	1·7 above	5·5	Ditto	Ditto	− 26 0	+ 13 30	Both attractions gradual.
34	M. B. No. 2	Ditto	5·5	Ditto	Ditto	+ 30 0	+ 13 30	The same as No. 32; both anomalous.
35	M. B. No. 1	4·5 above	6·0	N. 55 E.	Ditto	− 5 30	+ 35 30	Attractions very gradual.
36	M. B. No. 2	Ditto	6·0	Ditto	Ditto	− 0 0	+ 35 30	
37	M. B. No. 1	0·0	4·7	W.	+ 3 30	− 50 0	+ 8 0	Motion regular, but quick.
38	M. B. No. 2	0·0	4·7	N.	0 0	0 0	0 0	No motion in the needle.

Anomalous action of red-hot iron.

One of the most remarkable results of these experiments is, that the anomalous action of the bar between a bright-red and blood-red heat *increases* as we raise the bar above the needle, and becomes a *maximum* at the centre of the bar; whereas at low temperatures the action of a bar of iron under the very same circumstances goes on diminishing as the bar is raised, and becomes a minimum at the centre. When the needle is placed at the height of the centre of the bar, when heated to produce the anomalous effect, the smallest displacement is sufficient to change the sign and the quantity of the deviation.

Mr Barlow made some experiments with a twenty-four pound ball of iron, but the heat was too intense to allow any very accurate observations to be made. The results however, were as follow:—

Cold attraction	+ 13° 30′	deviation.
Red heat	− 3 30	...
White heat	0 0	...
Blood-red heat	+ 19 20	...

No effect whatever was produced on the needle by heated bars of copper.

In order to explain the singularly anomalous action above described, Mr Barlow supposed, that during the cooling of the bars, the extremities where this cooling is most rapid become magnetic before the rest of the metal, and that there results from this a complex action. He allowed, how-

Influence of Heat on Magnetism.

ever, that this supposition does not sufficiently explain all the observed phenomena. The explanation given by Professor Kupffer is more satisfactory. In weakly magnetized bars the points of indifference are very near the extremities; but in Mr Barlow's experiment the magnetism communicated to soft iron by the earth being nothing at a bright-red, and reaching its maximum at a blood-red heat, there is probably formed a point of indifference at each extremity of the bar. If this is the case, the raising of the bar places the needle in front of points which are beyond the point of indifference, and which possess a magnetism opposite to that of the extremity itself. At the first epoch of cooling, this opposite magnetism should even increase to a certain point, and the more as we approach the middle of the bar; but in proportion as the magnetism of the bar increases, the point of indifference will approach its middle, and the phenomena of ordinary attraction reappear.

M. Kupffer's explanation.

SECT. III.—*On the Effects of Heat on the Distribution of Magnetism in Magnets.*

Effect of heat on the distribution of magnetism.

M. Coulomb was the first philosopher who investigated the important subject of the influence of heat on the distribution of magnetism in needles and magnets.[1] He took a bar of steel 162 millimetres long, 14 wide, and weighing 82 grammes. This bar was brought to a cherry-red heat, about 900°, and cooled slowly in the air, so as to have no temper. It was then magnetized to saturation at the temperature of about 12° Reaumur. In this state the time of making *ten* oscillations was observed. Its temperature was again raised successively so many degrees, and after being cooled, the time of performing ten oscillations was again measured. The following were the results:—

Temperature in degrees of Reaumur.	Time of performing Ten Oscillations.
12°	93^s
40	97·5
80	104
211	147
340	215
510	290
680	very great.

Hence it is obvious that the magnetic intensity of the bar diminishes rapidly as its temperature is raised.

From another set of experiments, Coulomb concludes that the tempering of a bar previous to its being magnetized has no influence until the heat at which it is tempered becomes about 750°. When the tempering is at 900°, the bar will take double the magnetic force that it did at 12°; the ratio of the time of ten oscillations being 63^s and 93^s, the squares of which, to which the magnetic forces are proportional, are nearly as one to two.

After the magnet had received the hardest temper at 950°, it was magnetized to saturation. When it was brought back, by annealing, to lower temperatures, and again magnetized, the effects were as follow:—

Temperature.	Time of Ten Oscillations of a Bar tempered at 95°.
12°	63^s
80	66
214, blue colour	80
410, colour of water	170

Hence we see that the progressive rise of temperature alters the magnetism of the bar much more when it had been first tempered towards 900° and cooled slowly, than when it had been first put into the annealed state.

When in the annealed state the bar is exposed only to temperatures below 500°, it receives its original force by being again magnetized; but in the state of temper it is not so. Each rise of temperature diminishes perceptibly the magnetic force which the bar can receive from being again magnetized. This is shown in the following table:—

Influence of Heat on Magnetism.

Annealing Temperature.	Time of performing Ten Oscillations when again magnetized.
12°	63^s
214	64·5
410, colour of water	70
900, cherry-red	93

The bar, therefore, attained its maximum energy when tempered at 900°. It then performed ten oscillations in 63^s Setting out from this term, the directive force diminished in proportion as the annealing temperature increased. At 900° the bar, magnetized anew to saturation, employed 93^s to make ten oscillations, as in the first experiments, which ought to have been the case, as it was brought back to the same state of perfect annealing from which it was at first taken.

The bars used by Coulomb were about thirty times as long as they were thick, and with such bars similar results were always obtained. But this was not the case with larger bars. Having taken a steel wire 326 millimetres long, and 4 in diameter, he tempered it at 820°, magnetized it to saturation, and determined its directive force. He repeated the same operation after having annealed it at different temperatures, and the following were the results:—

Annealing Temperature.	Time of Ten Oscillations.
12°, temperature of atmosphere	89^s
320, colour of water	75
450, deep red	68
530, less deep red	70
900, bright cherry-red	76

Here the hard temper gives the weakest directive force, as we have already seen in the preceding experiments. The maximum effect takes place when the wire is annealed at about 450°, and this result is a general one for all wires and plates whose length is very great relative to their width.

This result seems to be connected with a particular mode of distribution of free magnetism. In bars whose length does not exceed thirty times their diameter there is never more than one magnetic centre, which is in the middle of the bar. But when the ratio of the length to the breadth is greater than this, magnetizing it produces always three centres, one in the middle of the bar, and the other two at equal distances from its extremities. This effect is shown in fig. 36, and in fig. 37. The effect of placing such a magnet in iron filings is shown in fig. 37; and in fig. 36 the curve of the intensities is seen to cross the axis between the centre C and the poles A, B, the two new centres being at C′ and C″.

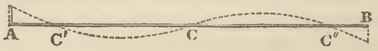

Fig. 36.

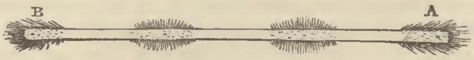

Fig. 37.

M. Coulomb found that the distance C′A, C″B of the two new centres from the extremities of the magnet varies with the temper, and the annealing heat is shown by the following results obtained with a wire-magnet 326 millimetres long:—

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[1] Biot, *Traité de Physique*, tom. iii., p. 106.

Influence of Heat on Magnetism.

	Time of Ten Oscillations.	Distances of the Centres C′, C° from the Centre C, the Middle of the Magnet.	
		C′	C°
Hard temper	89	98	98
Annealed at the colour of water	75	63	63
Ditto at dark-red heat	68	43	43
Ditto at cherry-red	76	0	0

In proportion as the annealing heat increases, the two centres C′, C″ approach each other, and are reunited with the centre C at a cherry-red heat. This last result is very important in the construction of compass-needles. Coulomb regards the *dark-red* as the best annealing heat for needles or bars whose length exceeds thirty times their thickness, and the state of hard temper for those where the ratio between the length and the thickness is less.

It is extremely probable, as M. Biot supposes, that when magnets are larger in proportion to their thickness than those used in the preceding experiments, a greater number of centres will be produced, were it from no other cause than the reaction of the plate upon itself.

M. Kupffer's experiments.

In examining the influence of temperature on magnets, Professor Kupffer began by examining the effect of heat in altering the distribution of magnetism. For this purpose he took a parallelopiped of tempered steel, 503 millimetres long, 15½ wide, and 5 thick, and having magnetized it to saturation, he heated it, and allowing it to cool slowly, he submitted it to examination. The magnet was placed vertically, as at *a′b′*, and a needle suspended by a silk fibre was made to oscillate before any point *ab*, in order to determine the intensity of magnetism at that point. In this way he obtained the following results:—

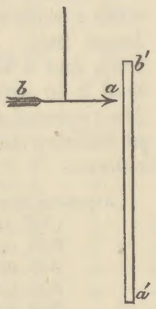

Fig. 38.

Distance *ab′* in Millimetres.	Magnet not heated.	Same Magnet heated to 80°, and examined after cooling.
	Magnetic Force.	Magnetic Force.
156	0·5569	0·4376
136·5	0·7374	0·5765
116·5	0·9455	0·7280
96·5	1·1862	0·8897
76·5	1·4311	1·0559
56·5	1·6518	1·1929

Hence it appears that the bar heated to 80° had not only lost much of its magnetic virtue, but that this loss was not uniform along the whole length of the bar, being greater towards the extremities *a′*, *b′* than towards the middle. This may be easily seen by dividing the forces in columns 2 and 3 by one another, when it will appear that the quotients are greater for points nearest *a′* and *b′*.

M. Kupffer next studied the changes which take place in the forces of a magnetic needle when its temperature is increasing, the heat being kept constant during the time of each experiment. He used a cylindrical needle of fused steel, 0·57 millimetre long, and 2·395 grammes in weight. The temperature increased from 8½° to 18°, and the deviation of 300 oscillations varied from 777½ to 781, which shows, as Coulomb had previously observed, that the magnetic force diminished as the temperature increased. By another series of experiments, M. Kupffer has shown that the diurnal variations of the needle did not at all affect these results.

In order to determine the law of the decrease of the magnetic forces at temperatures above 30°, he made a needle oscillate above a newly magnetized bar 0·5 millimetre long, the opposite poles looking to each other, and he raised the temperature of the bar from 13° to 80° by means of hot water. At 13°, the needle, when by itself, performed 300 oscillations in 762^s, and in presence of the magnet it lost only 429^s. When brought to the temperatures in the table, and then cooled, the oscillations of the needle were observed.

Influence of Heat on Magnetism.

Temperature of the Magnet.	Duration of 300 Oscillations.
13° Reaumur	429 seconds.
80 ...	476
21 ...	464½
13 ...	463
11 ...	462½

Hence it appears that the magnetic force diminishes with heat, and that a magnet at the temperature of 13°, when heated to 80°, and then cooled to 13, does not resume its first magnetic state, which is diminished. The cause of this is, that in cooling slowly the bar loses a part of its temper, and consequently a part of its free magnetism.

From these observations M. Kupffer deduces the following formulæ, which represent with great accuracy the influence of temperature, viz.:—

$$x = \frac{n}{\sqrt{c + \mathrm{F}}}$$

$$x = \frac{n}{\sqrt{\left(c + \mathrm{F} - \frac{(1-q)^{\mathrm{F}}}{67}\right)(t-13)}},$$

where c is the force exerted by the earth on the oscillating needle.

x, the number of seconds in which n oscillations are made.

F, the force exerted by the bar at the same temperature.

x', the number of seconds which the same needle employs at the temperature t.

p, the intensity of the magnetic force of the bar at 13°; and

q, the intensity of the same force at 80°.

M. Kupffer proceeded to examine the effects which the heating of only one pole of a magnet produced upon the distribution of its magnetism. With this view he placed a magnet parallel to a needle suspended horizontally, the dissimilar poles being placed opposite to each other. The needle will not remain in the magnetic meridian unless its neutral point and that of the bar are in the same line perpendicular to the needle. This position may be found by a few trials. When, by shifting the magnet, its neutral point approaches one of the poles of the needle, and always in the same direction, this pole will be repelled, because the opposite pole of the needle is more strongly attracted by the corresponding pole of the magnet, which is brought near it, while the other is removed from it.

Let us now heat the north pole of the magnet; the south pole of the needle opposite to it will be attracted. Hence it is clear that the point of indifference, or neutral point, has receded from the heated pole, or from the pole whose magnetic intensity is diminished, which agrees with the law of Coulomb. The following results were obtained with a magnet 0·5 millimetre long, the needle being placed in the magnetic meridian:—

Temperature of the extremity of the Bar.	Duration of 100 Oscillations.
0° Reaumur.	275·5 seconds.
13 ...	276
40 ...	278
56 ...	279·5
15 ...	277·5
11 ...	277

When the magnet had cooled slowly, the needle returned gradually to its first position; but it never recovered it entirely. By the earth's action only, the needle performed 50 oscillations in 207^s.

When a bar of soft iron was substituted for the magnet,

Action of Simple Iron Bodies on the Magnetic Needle.

and placed in the magnetic meridian, it was magnetized by the action of the earth. When one of its extremities was heated, the pole of the needle next it was *attracted* instead of *repelled*, the neutral point having *approached* to the heated extremity, in place of *receding* from it as formerly. Hence the magnetic force of the iron was *increased* by heat.

Mr Christie's experiments.

In examining the diurnal deviations of the needle when under the influence of magnets, Mr Christie conceived that the deviations might be partly the effect of changes in the temperature of the magnets; and he therefore undertook a series of experiments to determine the precise effects of changes of temperature on magnets. By a peculiar apparatus, and a method of observation which our limits will not allow us to introduce, he obtained the following results:—

Mean Temperature of the Magnets. Fahr.	Difference of Heats in successive Observations.	Magnetic Intensity.	Variation of Intensity for 1° of Fahr.
62°·05	− 3°·00	212·5620	0°·1268
59 ·05	+18 ·60	212·9423	0 ·1247
77 ·65	− 3 ·65	210·6228	0 ·1004
74 ·00	− 3 ·35	210·9892	0 ·1279
70 ·65	− 3 ·50	211·4178	0 ·1193
67 ·15	− 3 ·35	211·8353	0 ·1138
63 ·80	− 1 ·75	212·2167	
62 ·05		212·4640	0 ·1413

By discussing these results, Mr Christie concludes that 0·1226 is the mean variation of the intensity of the magnets, from a change in their temperature of 1° between the temperatures of 59°·05 and 77°·65. Taking the case where the intensity at 60° was 218, the change for 1° was 0·123; and supposing the intensity to be 1, each degree will produce a diminution of 0·000564.

From a number of experiments made with a balance of torsion, the needle being suspended by a brass wire $\frac{1}{460}$th of an inch in diameter, Mr Christie ascertained the following facts:—

1. Beginning with −3° of Fahrenheit, up to 127°, the intensity of magnets decreased as their temperature increased.

2. With a certain increment of temperature the decrement of intensity is not constant at all temperatures, but increases as the temperature increases.

3. From a temperature of about 80°, the intensity decreases very rapidly as the temperature increases; so that if, up to this temperature, the differences of the decrements are nearly constant, the differences in the decrements also increase.

4. Beyond the temperature of 100° a portion of the power of the magnet is permanently destroyed.

5. On a change of temperature, the most considerable portion of the effect on the intensity of the magnet is produced instantaneously, showing that the magnetic power resides on or very near the surface.

6. The effects produced on soft iron by changes of temperature are directly the reverse of those produced on a magnet; an increase of temperature causing an increase in the magnetic power of the iron. This was observed between the temperatures 50° and 100° Fahr. Mr Christie regards this fact as a strong argument against the hypothesis, that the action of iron upon the needle arises from the polarity which it receives from the earth.[1]

CHAP. VI.—ON THE ACTION OF SIMPLE IRON BODIES ON THE MAGNETIC NEEDLE.

Action of simple iron bodies on the needle.

Mr Barlow undertook the interesting experiments which we are about to describe, with the view of discovering some method of correcting the local attraction of a ship's guns and other iron on the compass-needle.

Action of Simple Iron Bodies on the Magnetic Needle.

His attention was first directed to the action of solid spheres and spherical shells of iron; but he afterwards applied the principles to which he was led to the action of bars and plates of simple iron, and to irregular masses. We shall therefore lay before our readers, in three separate sections, the results of his experiments and theoretical investigations respecting these two forms of unmagnetized iron.

SECT. I.—*On the Action of Spheres and Spherical Shells of Iron on the Magnetic Needle.*

Action of spheres on the needle.

The earliest experiments of Mr Barlow, by which he was led to some of the properties of iron spheres, were made in an imperfect manner; but the phenomena were such as to induce him to construct an apparatus capable of affording him the most accurate measures of the deviation of the needle.

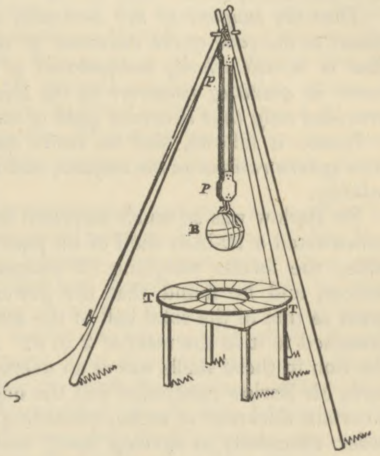

Fig. 39.

The apparatus which he finally employed is shown in fig. 39. It consists of a large and steady round table TT, having its surface horizontal. The points of the compass are laid down on its upper face. In its centre is a hole 18¼ in. wide, for receiving an 18-inch or smaller iron shell or ball B, which is suspended above it by pulleys *p*, *p*, which allow the observer to raise or lower it at pleasure. When a diameter of this table is brought into the magnetic meridian, Mr Barlow found, that in whatever part of the table a compass-needle was placed, except in the meridian, the *south* end of the needle was drawn to the ball when the latter was wholly above the table, as in the figure. The attraction increases as the ball descends, till at a certain point it is a maximum, and then decreases again towards zero as the ball descends farther. Hence it is clear, that there is all round the ball a position where the attraction is zero; and it was easily observed that these points lay in a plane inclined to the horizon. In this way Mr Barlow established his fundamental principle, that—

In every ball or shell of plain unmagnetized iron there exists a plane of no attraction, or a plane in which the iron produces no disturbance on the needle, and which plane inclines from north to south (magnetic), forming with the horizon an angle equal to the complement of the dip.

This line on the surface of the ball may be called the magnetic equator; and, taking the meridian which passes through the east and west points as the first, Mr Barlow is able to designate every part of his iron sphere by the magnetic longitude and latitude of that point.

Mr Barlow therefore proceeded to determine whether the quantity and deviation at any point could be expressed by any function of the latitude and longitude of that point, when the mass of the ball and the distance of the needle from it were constant. From these experiments, which it is unnecessary to detail, he found—

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[1] See *Philosophical Transactions*, 1825, p. 1-65.

Action of Simple Iron Bodies on the Magnetic Needle.

Professor Barlow on the action of iron spheres.

That the tangent of the deviation of the needle is proportional to the rectangle of the sine and cosine of the latitude, or to the sine of the double latitude.

By observing the deviations throughout a great circle in which the longitude was constant, and also in a circle in which the latitude and longitude were variable, he found the following law:—

That the tangent of the deviation of the needle is nearly proportional to the sine of the double latitude multiplied by the cosine of the longitude.

By comparing the constant numbers obtained on the preceding principles at different distances *from the centre of the sphere,* Mr Barlow found,—

That the tangent of the deviation is inversely proportional to the cube of the distance.

The remaining object of Mr Barlow's inquiry was a very interesting one, namely, to determine the law of the deviation as dependent on the mass of the iron ball by the action of which it was produced. The result was equally new and unexpected. He found,—

That the tangent of the deviation was directly proportional to the cube of the diameter of the ball or shell; but that it is still wholly independent of the mass, being the same in quantity whatever be the thickness of the metal, provided only that it exceed $\frac{1}{20}$th of an inch.

Hence it follows, *that the entire magnetic power of an iron sphere resides on the surface, and is independent of the solidity.*

Mr Barlow was so much surprised at this result, that he constructed a 10-inch shell of tin plate and another of iron plate, the former weighing 43 ounces and the latter 45 ounces, and he found that the power of neither was so great as that of the solid ball of the same diameter, but approached to it in the ratio of 2 to 3. As the thickness of the iron in these shells was at an average about $\frac{1}{30}$th of an inch, Mr Barlow concluded that the magnetic fluid requires a certain thickness of metal, exceeding $\frac{1}{30}$th of an inch, in order effectually to develop itself, and act with its maximum energy.

This important result was some time afterwards verified by Captain Kater, with three cylinders, one of soft iron, and $\frac{1}{10}$th of an inch thick; another of what is called chest-plate, 0·185 of an inch thick; and the third solid. The deviations produced by these three cylinders, when reduced to the same extent of surface, were 141, 184, and 187, thus proving that the cylinder whose thickness was only 0·185, or between $\frac{1}{5}$th and $\frac{1}{6}$th of an inch thick, had the same magnetic power as a solid cylinder of iron. The distribution of magnetism on the surface of magnetic bodies presents us with another interesting analogy between the magnetic and electric fluids; and it deserves our particular notice, that in the results obtained by Mr Barlow, the action of the sphere is related to the centre of its mass, and not to the poles of its magnetic equator.

Mr Barlow next proceeds to the investigation of analytical formulæ, which shall exhibit the action of iron spheres upon a magnetic needle. In this inquiry he sets out with the established experimental fact already mentioned, *that the entire magnetic power of an iron sphere resides on the surface, and is independent of the solidity;* and he proceeds on the following hypothesis:—

1. Magnetic phenomena are due to the existence of two fluids in a greater or less degree of combination, and such that the particles of the same fluid repel, and those of an opposite nature attract, each other.

2. These fluids in iron bodies exist naturally in a state of combination and equilibrium till that state is disturbed by some exciting cause.

3. But if a body already magnetic, *i.e.*, one in which the fluids are held in a state of separation, be brought within the vicinity of a mass of iron, such as is supposed above, the concentrated action of each fluid in the magnetized body will act upon the latent fluids in the quiescent body, by repelling those of the same, and attracting those of the contrary kind, and thus impress upon the latter a temporary state of magnetic action, which will remain only while the two bodies maintain their respective situations.

Action of Simple Iron Bodies on the Magnetic Needle.

Professor Barlow on the action of iron spheres.

4. The quantity of action impressed upon the iron body will depend, 1*st*, upon the intensity of the exciting magnet; 2*dly*, upon the capacity of the quiescent body for magnetism, or the quantity of those fluids contained in it; and, 3*dly*, upon the cohesive power of the iron; which latter quality determines the depth to which the exciting magnet is able to disengage the two fluids.

The above embraces every case, namely, of any magnet, natural or artificial, developing the magnetism in any given iron body; but the displacement occasioned by the magnetic action of the earth, or spheres of iron, is more limited in its results, and more susceptible of correct mathematical investigation.

5. In this case, for instance, we may suppose the action to take place on every particle of the mass in lines parallel to each other, and corresponding in direction with the dipping needle; also, that every particle is at the same distance from the centre of the disturbing force, and consequently that the displacement in each particle is equal also.

6. For the sake of illustration, let AEBD represent a sphere of iron in its non-magnetic or quiescent state, and let CM be the line on which the terrestrial magnetism is exerted from a centre of action M, which is at such a distance that the diameter of the sphere is inconsiderable in comparison with it; then every particle on its surface, and to a certain distance within it, will be acted upon by equal powers, and in directions parallel to each other, whereby the fluids in the quiescent body, before in a state of combination, will be separated in each particle; and the two fluids may now therefore be conceived to form two spherical shells $AeBd$, $Ae'Bd'$, whose centres of action will be c, c', their distances from each other being greater or less, according to the circumstances stated in No. 4.

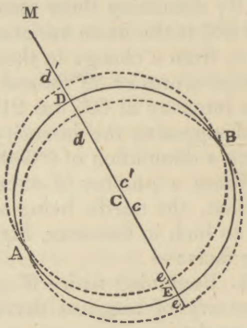

Fig. 40.

7. Therefore, in computing the action of such a mass of iron, in its temporary state of magnetism, upon a distant particle of magnetic fluid, Mr Barlow refers it to these centres, and assumes that the law of action in this, as in other cases of emanating forces, is inversely as the squares of the distance.

By means of this hypothesis Mr Barlow arrives at the following formula for the deviation Δ of a horizontal needle.

$$\text{Tan. } 7\,\Delta = \frac{\text{C}}{\text{M}} \cdot \frac{3r^2}{2d^3 \cos \delta} (2\lambda \,.\, \cos l),$$

where r = radius of the iron spheres;
d = the distance of the needle from the centre of the spheres;
λ = the complement of the magnetic latitude;
l = the complement of the magnetic longitude;
δ = the dip of the needle; and
$\frac{\text{C}}{\text{M}}$ = 1·0539 a constant quantity for cast-iron balls and shells, of every diameter, and for all distances and positions.

From this formula it necessarily follows,—

1. That though the development of the magnetism of the spheres takes place by the hypothesis only at the sur-

Action of Simple Iron Bodies on the Magnetic Needle.

face, yet the effect, as shown by the tangent of the deviation, is proportional to the cube of the diameter.

2. That the tangent of deviation is inversely as the cube of the distance.

3. That the tangent of the deviation is proportional to the sine of the double latitude and cosine of the longitude, the latter being extended from the east and west points.

These are the very laws which Mr Barlow had deduced from experiment, and he has established the correctness of his formula by comparing it with a great body of experiments made by himself and Mr Christie, and also with observations on the dipping needle.

Sect. II.—*On the Action of Simple Iron Bars and Plates on the Magnetic Needle.*

As spherical bodies possess the peculiar property of having their centre of attraction in the centre of the mass, the former becomes a fixed point whatever be the distance of the magnetic needle. As this is not the case, however, with bodies of other forms, such as bars and plates, Mr Barlow was desirous of ascertaining whether, in these cases also, the magnetic attraction of the body could be referred to the action of two centres indefinitely near to each other in the general centre of attraction of the surface of the body, viz., that point into which, if all the matter of the surface were collected, its action on the centre of the needle would be the same as the action of the whole body in its natural form.

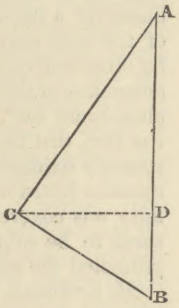

Fig. 41.

In pursuance of this plan, he supposes AB to be a bar of iron, and C the place of the needle, and, letting CD fall perpendicular on AB, he joins AC, BC. He then finds the following expression for the deviation :—

$$\tan \Delta = \mathrm{A}\,\frac{mn \cos l}{(m^2 + n^2)^{\frac{1}{4}}},$$

A being a constant quantity, l the longitude, m the force in the direction DC, and n the force in DA. In the experiments with which Mr Barlow proposed to compare this formula, the needle was placed due east and west of the bar, the longitude of its position was zero, and hence $\cos l = 1$. The formula, therefore, becomes

$$\tan \Delta = \mathrm{A}\,\frac{mn}{(m^2 + n^2)^{\frac{1}{4}}}, \text{ or } \tan \Delta \cdot \frac{(m^2 + n^2)^{\frac{1}{4}}}{mn} = \mathrm{A},$$

whatever may be the distance of the needle or its position, provided its longitude be zero.

Mr Bonnycastle's experiments.

The following experiments were made by Mr Charles Bonnycastle, with a bar 24 inches long and $1\frac{1}{4}$ inch square, inclined in the direction of the dipping needle. The magnetic needle was placed to the east and west of the bar, first opposite to its centre, and then at every 3 inches from the centre to the extremities, at the distance of 12 and 16 inches from the axis of the bar. The following were the results :—

Distance of Compass from Bar in inches.	Distance below Centre.	Observed Deviation.	Value of $\frac{mn}{(m + n^2)^{\frac{1}{4}}}$	Values of A.
16	3	2° 20′	·00240	17·03
16	6	4 25	·00438	17·62
16	9	5 45	·00563	17·88
16	12	6 0	·00596	17·63
12	3	5 20	·00484	19·28
12	6	10 0	·00899	19·62
12	9	12 0	·01152	18·45
12	12	11 30	·01160	17·54
				Mean 18·13

Influence of Magnetism on Chemical Action.

These results Mr Barlow justly regards as a further proof of the accuracy of the principles upon which his hypothesis is founded, and of his general deduction that the action of plain unmagnetized iron on a compass needle may be referred to two poles indefinitely near to each other in the common centre of attraction of the surface of the body.

Mr Bonnycastle performed another series of experiments with a plate of malleable iron 12 inches square and half an inch thick, and he obtained results almost equally accordant with Mr Barlow's hypothesis.

Sect. III.—*On the Action of Irregular Masses of Iron on the Magnetic Needle.*

Action of irregular masses of iron.

Mr Barlow was next desirous of ascertaining if the same law which applied to spheres, bars, and plates, was true in irregular masses of iron, such as a 24-pounder gun; an experiment peculiarly applicable to the object he had in view. He found that the plane of no attraction existed in the most irregular masses of iron, and the agreement between the observed deviations produced by the gun, and those calculated by his formula, was such as to satisfy him that the same laws applied to irregular as to regular masses of iron; and he was thus furnished with the means of computing the local attraction of a ship's guns upon the compass under all circumstances, and in all parts of the world.

Experiments of Mr Lecount.

These views were strikingly confirmed by several ingenious observations, made, without knowing of Mr Barlow's labours, by Mr Lecount, with bars, handspikes, mast rings, and various other iron bodies, from which he concluded "that a plane or circle held east and west (magnetic), and at right angles to the direction of the dipping needle, divides the north from the south magnetic effluvia, each lying on that side to which the dipping needle points; and by referring the position of all iron bodies to this plane, the plane of section shall divide the two into north and south polarity, provided it be of uniform thickness, or, if not, the section must be drawn through its centre of (gravity) attraction."[1]

CHAP. VII.—ON THE INFLUENCE OF MAGNETISM ON CHEMICAL ACTION.

Influence of magnetism on chemical action.

An opinion had long prevailed among philosophers that the phenomena of magnetism and electricity had a similar origin; and hence various observers had been led, previous to the discovery of electro-magnetism by Oersted, to inquire if any actions of a chemical nature could be produced by magnetism.

Experiments of Ritter.

The German philosopher Ritter was the earliest and the most active of these inquirers. He maintained that a magnetic wire, combined with another wire not magnetized, produced contractions in a frog, the south pole of the wire-magnet producing stronger contractions than the unmagnetized wire; and as he had constantly observed that the metals most susceptible of excitation excited the strongest contractions, he concluded that the south pole of a magnet has a greater affinity for oxygen than simple iron, and the north pole a less affinity. Hence he was led to confirm these views by means of several chemical reagents. He placed a magnetized wire upon pieces of glass in an earthenware dish containing weak nitric acid, when he found that the south pole was more corroded by the acid than the other, and was soon encircled with a deposition of oxygen greater than that at the other pole. In another experiment he took two flasks filled with tincture of turnsol, in one of which he placed the two south poles of two wire-magnets,

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[1] Lecount *on the Magnetic Properties of Iron Bodies.*

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and in the other the two north poles of two similar magnets. In the last flask the oxidation of the wires was much greater than in the first.

Experiments of Ritter.

The difference in the oxidation of the south pole was exhibited by Ritter in another way. He took three small and equal bottles filled either with pure or slightly acidulated water, and having placed in one the south pole of a wire-magnet, in another the north pole, and in the third the extremity of an unmagnetized wire of the same length, he observed that the south pole first began to deposit oxide, the unmagnetized wire next, and the north pole last. In order to exclude the access of air, the surface of the water should be covered with very fresh oil of almonds; and as light accelerates oxidation, none of the bottles should be more exposed to the sun than the rest. In support of this last observation, Ritter exposed two iron wires to the sun when placed in water, and having covered one of the bottles with black paper, he found that the wire in the uncovered bottle was oxidated more rapidly than the other.

Ritter repeated the preceding experiment with the three bottles containing an infusion of litmus in place of acidulated water. The south pole reddened the infusion most, the unmagnetic wire less, and the north pole least of all. A week is required to produce a distinct effect; and in order even to effect this, Ritter found it necessary to add as much acetic acid as would incline the infusion to red without completely changing its colour.

The following experiment of Ritter, if correctly repeated, establishes the same result. We shall give it nearly in his own words:—"Sixteen magnetic wires, of equal size and power, were placed in six vessels, all equally full of a mixture of one part nitric acid and thirty-six parts water, in the following manner: In the first glass were placed two wires, one with the north pole immersed in the fluid, the other with the south, and not more than half a line asunder; in the second, the same, but the wires an inch and three-fourths apart; in the third and fourth were each three wires, with the south poles of all immersed, but their distances in the two glasses different, as in the first and second; in the fifth and sixth were wires similarly arranged, but with the north poles immersed. Different quantities of oxide were gradually deposited, and, to express the whole in a few words, we will call the south pole S, the north pole N, their greater distance g, and their less p, and we will express the order of oxidations as follows: $SNg > SNp > 3Sp > 3Sg > 3Np > 3Ng$. On the nineteenth day it was observed that the loss of fluid by evaporation had not been equal in all the vessels, but took place in the inverse order of the oxidations. All the magnetic wires were weakened in power; NSg least, NSp more; of the wires $3Sp$, two had lost less power than the third; and in like manner $3Sg$, $3Np$, $3Ng$, had each two left more powerful than the third; the strongest were equal to NSg."

Experiments of Muschman, and Hansteen.

The next experiments on this subject were made by M. Muschman, professor of chemistry in the university of Christiania, who endeavoured to ascertain the effect of the earth's magnetism on the precipitation of silver. In his chemical course in 1817, when he was desirous of explaining the chemical theory of the tree of Diana, he took a tube like a syphon, and poured mercury into it, which accordingly occupied the lower part of the two branches: above the mercury he poured a strong solution of nitrate of silver. He then placed the two branches of the syphon so that the plane passing through them was in the magnetic meridian, and after standing a few seconds, the silver began to precipitate itself with its natural lustre; but it accumulated itself particularly in the northern branch of the syphon, while that which was less copiously precipitated in the other branch had a less brilliant lustre, and was mixed with the mercurial salt deposited from the solution. M. Muschman and Professor Hansteen repeated this experiment in an improved form with the very same result. On this occasion they used simultaneously two syphons prepared in the same manner, the one being placed in the direction of *north* and *south*, and the other in that of *east* and *west*. The silver began to precipitate itself in the direction of *north* and *south*, and it particularly raised itself in the *north* branch with a lustre more brilliant than in the *south* one; whereas in the syphon whose plane lay *east* and *west*, *no change had taken place even at the end of twelve hours.* Hence the two Norwegian philosophers concluded, with some reason, that the magnetism of the earth had an influence on the precipitation of silver from a solution of its nitrate; and M. Muschman inferred, from the experiment, the identity of galvanism and magnetism. He regarded every dissolution as the result of a galvanic effect, the precipitated metal carrying off the electricity set at liberty, and carrying itself, in order to be disengaged, to the place where it could find the opposite electricity, which was the north pole. M. Muschman considered this hypothesis confirmed by the geological fact, that at Königsberg silver was found in the metallic form, stretching from north to south; and the presence of the silver is always indicated by a certain quantity of pyrites and blendes. Hence he conceived that the silver had been insensibly united to sulphur, and that by the effect of the earth's magnetism alone it had been carried towards the copper and the zinc.

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Experiments of Fresnel;

M. Fresnel made a series of experiments with the view of decomposing water by the magnet. He proposed to produce an electric current in an electro-magnetic helix inclosing a bar-magnet covered with silk. The two ends of the wire were plunged in slightly acidulated water, and he observed very decided effects; but there were so many anomalies in the result, which he could not explain, that he abandoned the inquiry. He was particularly struck with the fact, that the wire which should be the positive one was strongly oxidated, whilst the other extremity preserved its metallic lustre during a whole week. The negative extremity was covered with a saline deposit, which he conjectured to be sulphate of lime, and which he supposed had protected the wire from oxidation.

of Erdmann.

M. Erdmann, after a very elaborate inquiry into the effects of magnets as chemical agents, came to the conclusion that the observed phenomena were due to the influence of other causes, which had not been sufficiently guarded against.

A curious fact, connected perhaps with the class of phenomena under our observation, was noticed by M. Lebaillif. He observed that the poles of a magnetic needle delicately suspended were repelled by pieces of antimony or bismuth that were brought near them.

CHAP. VIII.—ON THE LAWS OF THE MAGNETIC FORCES, THE MUTUAL ACTION OF MAGNETS, AND MAGNETIC CURVES.

SECT. I.—*On the Law of the Magnetic Force.*

Law of the magnetic force.

In our history of magnetism we have given very full details of the various attempts which were made by philosophers to determine the law according to which the intensity of the attractive and repulsive power of magnets varied with the distance at which these forces were exerted. Like all other laws, an approach to the discovery of it had been made by various philosophers; but the merit of its perfect establishment undoubtedly belongs to Dr Robison and Coulomb, the last of whom placed it beyond the reach of doubt. The difficulties which were to be overcome in this inquiry arose from the invariable co-existence of two opposite polarities in each of the two bodies whose mutual action was under examination; and this difficulty was increased from these polarities not being concentrated in particular points, but diffused in an unequal degree over each half of the magnet and the needle.

Researches of Coulomb

In this delicate inquiry Coulomb employed two methods. In the first he suspended a magnetic needle by a silk fibre, and when it was in the magnetic meridian, he presented to it at different distances another magnetic needle, and determined by observation and calculation the force with which they acted upon each other at these distances. A needle an inch long, weighing 70 grains, and magnetized to saturation, was suspended by a fibre of silk three lines long, and a steel-wire magnet 25 inches long was placed vertically in the magnetic meridian at different distances, so that its south pole was always ten lines below the northern extremity of the suspended needle. The needle was now made to oscillate when the magnet was at different distances from it, and the following were the number of oscillations in 60^s, the number being fifteen when the magnet was removed, and the needle influenced only by the magnetism of the earth.

Distance of a Wire-Magnet from the middle of the Needle.	Number of Oscillations in 60 seconds.
4 inches	41
8 ditto	24
16 ditto	17

By means of the formula for the pendulum, in which the forces are in the direct ratio of the square of the number of oscillations performed in the same time, Coulomb has computed their intensity. As all the forces concerned are in the plane of the magnetic meridian, the force which produces the horizontal oscillations depends on the parts of these forces which are decomposed in a horizontal direction. Now Coulomb had demonstrated that the magnetic fluid might be considered as concentrated at a point 10 lines from the extremity of the wire-magnet; but as the suspended needle was 1 inch long, its north pole was attracted at the distance of $3\frac{1}{2}$ inches, and its south pole at the distance of $4\frac{1}{2}$ inches, so that 4 inches was the mean distance at which, in the first experiment, the lower pole of the wire-magnet exerted its action on the two poles of the needle. In the second experiment the mean distance was 8 inches. But as the horizontal force which produces the oscillations is the square of the number performed in 60^s, the magnetic force of the earth will be 15^2, and the combined forces of the earth and the wire-magnet will, in the first, second, and third experiments, be 41^2, 24^2, and 17^2, so that the forces which emanate from the wire-magnet will be 41^2-15^2, 24^2-15^2, 17^2-15^2, whence we deduce the following results:—

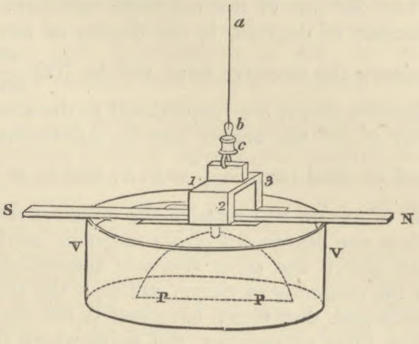
Mean Distance.	Force depending on the Action of the Wire-magnet.
1*st* experiment 4 inches	$41^2-15^2=1456$
2*d* experiment 8 ditto	$24^2-15^2=351$
3*d* experiment 16 ditto	$17^2-15^2=64$

The distances in the first and second experiments being as one to two, the variation of the force would have been exactly as the squares of these numbers had the force in the second experiment been 364 instead of 351; and the same would have been the case had the force in the second and third experiments been 332 and 83, instead of 351 and 64. This difference, therefore, requires to be investigated. Coulomb has accounted for it, and calculated the correction for these numbers in the following manner. In the experiments the action of the superior pole of the wire-magnet was neglected. The distance of its inferior pole from the centre of the needle was 16 inches, and the distance of the superior pole from the centre of the needle is nearly $\sqrt{(16^2+23^2)}$, so that the force of the former is to that of the latter nearly as 100 to 19. Hence, as the oscillations of the needle are produced by the action of these two poles, which exert their force in opposite directions, the square of the number of oscillations which the single action of the inferior pole of the magnet would produce, should be diminished $\frac{18}{100}$ths by the opposite action of the superior pole; so that 64 is only the excess of the real amount of the single action of the lower part of the magnet over $\frac{18}{100}$ths of the number which represents it. The true value will therefore be 79. The true intensities of the forces will, at the distances 4, 8, and 16 inches, be 1456, 351, and 79, or nearly in the inverse ratio of the squares of the distances.

M. Coulomb has in like manner demonstrated, that the repulsive force of similar poles follows the same law of the distance.

Coulomb's magnetic balance.

The *second* method employed by Coulomb requires the use of the magnetic balance, which is represented in figs. 42 and 43, which is a modification of the torsion balance already described in our article on ELECTRICITY. The suspending wire *ab*, fig. 42, carries at its lower extremity a pair of pincers *c*, which holds a stirrup 1, 2, 3, formed of a plate of very light copper. In this stirrup is placed a small piece of card covered with a coat of Spanish wax, on which is impressed the mark of the wire or bar of steel SN to be used, in order that it may always be put in the same position. Under the middle of the stirrup is fixed a vertical plane PP, wholly immersed in a vessel VV of water, the resistance of which may quickly stop the oscillations of the needle or magnet SN in the stirrup. When fitted up for the experiments under our consideration, the apparatus shown in fig. 42 is placed in a square box AB (see fig. 43), 3 feet wide and 18 inches high. At the height of 9 inches above the bottom is placed a horizontal circle of wood or copper, 2 feet 10 inches in diameter, and divided into degrees. On this box is placed a cross piece CD, which supports at its middle point a tube EF, 30 inches long, and terminating in a torsion micrometer at M. The pincer of this micrometer holds the upper end of a brass wire, to the other extremity of which is adapted a ring of copper intended to carry a steel needle.



Fg. 42.

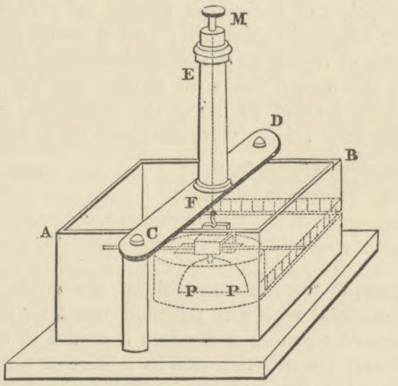


Fig. 43.

Before the commencement of the experiment, the box AB is placed so that the direction of the magnetic meridian passes through the divisions *zero* and 18° of the horizontal circle. The next step is to place in the stirrup a well magnetized steel needle NS, of a rectangular form, and to adjust the torsion micrometer M, so that the torsion of the wire is nothing when the needle NS is in the magnetic meridian, or that the magnetic meridian passes through the *zero* on the scale of the torsion micrometer. In the direction of the magnetic meridian a vertical ruler of wood or copper, 1 or 2 lines thick, is fixed, so that the end of the needle may come against it when it is in the magnetic meridian.

Coulomb now took two wire magnets 24 inches long and $1\frac{1}{2}$ in diameter, and he placed one of them in the stirrup, as at NS, and determined the force with which the magnetism of the earth drew it back into the magnetic meridian. For this purpose he twisted the suspending wire *ab* through

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two circles or circumferences, minus 20°, till the needle stopped 20° from the magnetic meridian, so that, considering the forces as nearly proportional to the arcs (when the angle is about 20°), about 35° of torsion were necessary to keep the magnetic needle one degree out of the magnetic meridian. The two circles of torsion, *minus* 20°, are equal to $2 \times 360° - 20° = 700°$; the degrees of torsion required to keep the needle 20° out of the magnetic meridian, or 700° of torsion, are a measure of the directive force of the needle when 20° out of the magnetic meridian. For any other number of degrees, δ, the degree of torsion necessary to balance the directive force will be $700 \frac{\sin \delta}{\sin 2°}$, because the directive forces are proportional to the sines of the angles. But at 20° the angles may be substituted for the forces, and we shall have $\frac{700\,\delta}{20} = 35\,\delta$; that is, as we stated above, 35° of torsion will balance the directive force of the needle when one degree out of the magnetic meridian. Coulomb now placed the other similarly magnetized wire vertically in the magnetic meridian, so that if the two wires had been prolonged, they would have met at the distance of *ten* lines from their extremities, the point where the magnetism of each acts as if it were concentrated there. He placed the similar poles of each opposite to each other, and consequently the horizontal needle or wire was repelled out of the magnetic meridian; and it took a position at which the force of repulsion of the vertical needle or wire was balanced by the united forces of torsion and the earth's magnetism, which tended to bring the horizontal wire to rest. The following results were obtained after different trials:—

Circles of Torsion given to the suspending wire by the Torsion Micrometer.	Observed Angles of Repulsion.
0	24
3	17
8	12

Now, in the first experiment, the angle through which the horizontal wire was repelled was 24°, reckoning from the zero of torsion; and when it rested in this position, it was driven towards the zero by a force of torsion of 24° *plus* the directive force of the earth's magnetism, which being 35° for every 1°, amounts to $24 \times 35° = 840°$. The total repulsive force was therefore $840° + 24° = 864°$.

In the second experiment the torsion micrometer was turned round *three* circles, in a direction opposite to the 24° first produced; but notwithstanding this great torsion, the horizontal wire-magnet, repelled by the vertical one, returned only to 17° from the magnetic meridian. The force of torsion was therefore 3 circles $+ 17° = 1097°$: but the directive force for 17° is $17 \times 35° = 595°$, hence we have for the total repulsive force $1097° + 595° = 1692°$.

In the third experiment the torsion micrometer was turned round eight circles, and the wire magnet stopped at 12° from the magnetic meridian. The force of torsion was therefore 8 circles $+ 12° = 2892°$; but the directive force for 12° is $12 \times 35° = 420°$, hence we have for the total repulsive force $2892° + 420° = 3312°$.

As the arcs of repulsion are in these experiments so small, we may safely reckon them equal to their chords, and we obtain the following results:—

Distances at which the Repulsive Force is exerted.	Corresponding Repulsive Forces in Degrees of Torsion.
12	3312°
17	1692
24	864

Assuming 3312° as correct, the other numbers ought to have been 1650 and 828 instead of 1692 and 864, if the force varies inversely as the square of the distance. The differences 42° and 36° correspond nearly with a degree of error in the observed position of the moveable steel wire, since the directive force is 35° for every degree of deviation from the magnetic meridian. Such an error is certainly a very small one in experiments of this kind, and we therefore conclude that the attractive and repulsive forces of magnets decrease as the squares of their distances increase.

Had the experiments been made upon magnetic points, such an error would not have existed; but they were made with forces diffused over portions of the wire-magnet of some extent. In the last experiment (M. Biot remarks) "when the two wires were nearest each other, the influence of the points lying near the intersection was more weakened by obliquity than in the other experiment; or, in other words, there were at equal obliquities more points which acted in the greater distances (24 and 17) than in the smaller one (12). But as we did not take this augmentation into account, we ought to find that the repulsive force observed at the smaller distance, being reduced in the ratio of the square of the distance, gives for larger distances repulsive forces a little more feeble than those which were actually observed."

In the first method of observation, Coulomb was obliged to calculate the effect of the distant pole; but in the present method this was unnecessary, as the wire magnets were 2 feet long, and the greatest arc of repulsion, viz. 24°, corresponded to a distance of 5 inches between the repelling poles. The other poles were therefore at least four times more distant than those whose repulsive action was calculated; their direct action was therefore 16 times weaker, besides being greatly weakened by the extreme obliquity with which it acted. Had the wire magnets been shorter, the action of all the poles might have been taken into consideration.

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SECT. II.—*On the Mutual Action of Magnets.*

Mutual action of magnets.

We have already seen, from Professor Barlow's experiments on spheres and bars of soft iron, that they act upon needles, whether temporarily or permanently magnetized, as if their magnetism emanated from the centre of their surface, or from two points indefinitely near to each other. This, however, is not the case with permanent magnets, in which the magnetic force is concentrated in poles considerably distant from each other.

CASE 1. When the needle or a small magnet is placed in the line joining the poles of the other magnet.—In considering the mutual action of magnets, we shall suppose the larger one NS to be fixed, and the smaller one *ns* to have the form of a needle, moveable in a horizontal plane round the pivot in its centre A, B, or C. Let the needle then be placed at A, with its centre A in the line SN prolonged, and let us suppose that the magnetic forces emanate from points N, S; *n*, *s*, being the analogous poles of the needle. The north pole N of the magnet *attracts* the *south* pole *s* of the needle with a force inversely proportional to the square of N*s*, and *repels* the *north* pole *n* with a force inversely proportional to the square of N*n*. The effect of both of these forces is to bring *s* as near as possible to N, and to remove *n* as far as possible, that is, to place the needle in the same straight line as NS, as shown in fig. 44.

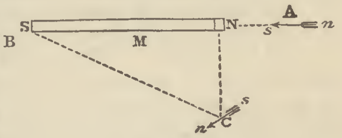

Fig. 44.

CASE 2. Let the needle *ns* be now placed at B, fig. 45, so that its centre B is anywhere in the direction of a right line MB perpendicular to the middle M of the magnet. When the centre of the needle is placed above M, it is quite clear that it will stand with its north pole *n* towards the south pole S of the magnet, and its south pole *s* towards the pole N. When the needle is removed to B, the same thing will happen; S will attract *n* with a force equal to *nb*, while N repels *n* with a force *nc*, a little less than *nb*, on account of the increase of distance. The result of these will be the

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force *na*, in the diagonal of the parallelogram *ncab*. In the same manner, the pole N will attract *s* with a force *es*, and the pole S will repel *s* with a less force *fs*, the resultant of which is *sg*; but as the poles S, N are equally strong, and act at equal distances upon the needle, the resulting force *an* must be equal to *gs*, and the needle will remain in that position, which is parallel to the axis SN of the magnet.

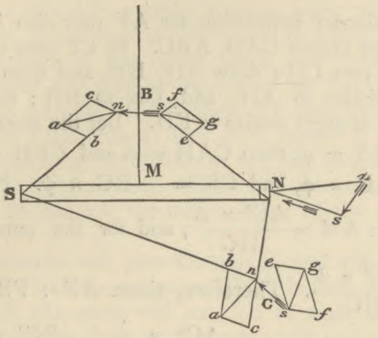

Fig. 45.

Case 3. When the centre of the needle is placed in an intermediate position, as at C, fig. 45, neither in the axis NS, nor in the perpendicular MB, it will take an intermediate position, which may be thus found. Its north pole *n* is shown in the figure as directed to the centre M of the magnet; but it cannot remain in this position; N repels *n* with a force equal to *nc*, and S attracts it with a force *nb* smaller than *nc*, from the greater distance. The resultant of these is *na*, which is very different from *ns*. For the same reason, the south pole *s*, repelled by S with a force *sf*, and attracted by N with a force *se*, will have a tendency to move in the direction *sg*, nearly equal and opposite to each other; it will therefore take a position *ns*, fig. 45, nearly at right angles to its former position. It will rest therefore in its new position with its north pole towards N, and its south pole towards S.

If we project upon paper the magnet and the needle placed in different positions, and make the forces of each pole of the magnet on each pole of the needle inversely proportional to the squares of the distances, it will be easy to find the position in which the needle will rest at any distance from the magnet, and at any position of its centre with regard to the axis of the magnet.

When a needle is exposed to the combined action of two magnets, as shown in the annexed figure, the phenomena, though capable of calculation by the principles already explained, are extremely perplexing and complicated when studied experimentally. Dr Robison, who first discovered and explained these phenomena, has given such an interesting account of them, that we shall make use of his description of the phenomena, leaving the explanation of them to the next section on magnetic curves.

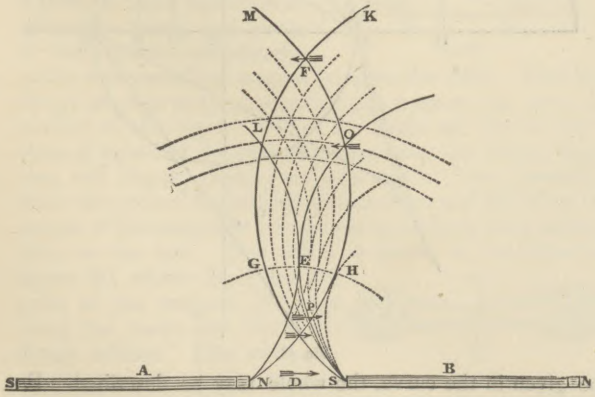

Fig. 46.

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"Two large and strong magnets, A and B, were placed with their dissimilar poles fronting each other, and about three inches apart. A small needle, supported on a point, was placed between them at D, and it arranged itself in the same manner as the great magnets. Happening to set it off to a good distance on the table, as at F, he was surprised to see it immediately turn round on its pivot, and arrange itself nearly in the opposite direction. Bringing it back to D, restored it to its former position. Carrying it gradually out along DF, perpendicular to NS, he observed it to become sensibly more feeble, vibrating more slowly; and when in a certain point E, it had no polarity whatever towards A and B, but retained any position that was given it. Carrying it farther out, it again acquired polarity to A and B, but in the opposite direction; for it now arranged itself in a position that was parallel to NS, but its north pole was next to N, and its south pole to S.

"This singular appearance naturally excited his attention. The line on which the magnets A and B were placed had been marked on the table, as also the line DF, perpendicular to the former. The point E was now marked as an important one. The experiments were interrupted by a friend coming in, to whom such things were no entertainment. Next day, wishing to repeat them to some friends, the magnets A and B were again laid on the line on which they had been placed the day before, and the needle was placed at E, expecting it to be neutral. But it was found to have a considerable verticity, turning its north pole towards the magnet B; and it required to be taken farther out towards F before it became neutral. While standing there, something chanced to joggle the magnets A and B, and they instantly rushed together. At the same instant the little magnet or needle turned itself briskly, and arranged itself, as it had done the day before at F, quivering very briskly, and thus showing great verticity. This naturally surprised the beholders; and he now found, that by gradually withdrawing the magnets A and B from each other, the needle became weaker, then became neutral, and then turned round on its pivot, and took the contrary position. It was very amusing to observe how the simply separating the magnets A and B, or bringing them together, made the needle assume such a variety of positions, and degrees of vivacity in each.

"The needle was now put in various situations in respect to the two great magnets, namely, off at a side, and not in the perpendicular DF. In these situations it took an inconceivable variety of positions, which could not be reduced to any rule; and in most of them it required only a motion of one of the great magnets for an inch or two, to make the needle turn briskly round on its pivot, and assume a position nearly opposite to what it had before."

In the preceding observations, the action of the one magnet tended only to change the direction of the other, and this change is clearly produced by the sum of the actions of the two poles of the magnet; for while the one pole tends to draw the one half of the needle into its position of equilibrium, the other pole repels the other half into the same position. The force, therefore, which thus acts upon a needle, is called the *directive force* of a magnet.

The *attractive force* of a magnet is, on the other hand, equal to the difference of the two forces exerted by its poles on the needle; and when the two forces happen to be equal, the attractive force will be nothing, and the needle will have no tendency to approach the magnet, though the directive power of the latter may be very great. This will be understood from fig. 45, when the needle *ns* is at right angles to the axis of the magnet. The attraction of the pole N for *s* is equal to its repulsion of *n*, and these two forces will neutralize each other, so as to prevent any ten-

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dency to approach N, even if the needle *ns* were free to do it. On the other hand, in fig. 44, where the needle at C has its south pole *s* more attracted by N than its north pole *n* is repelled by it, the predominance of the attraction would carry the needle towards N if it were at liberty. These views explain the well-known fact, that a needle floated on a piece of cork quickly places itself in the magnetic meridian; but it never will approach the north side of the vessel. In order to explain this fact, Dr Gilbert asserted that the directive power of a magnet extended much farther than its attractive power; a mistake which arose from his not having observed the effects of the simultaneous action of the four poles of the magnets which acted upon each other.

SECT. III.—*On Magnetic Curves.*

Magnetic curves.

The name of magnetic curves has been given to those curves into which an infinite number of very minute needles would arrange themselves when placed round a magnet, and at liberty to move round an axis. A rude idea of these curves is given by the appearance of iron filings when scattered upon a sheet of paper, and agitated immediately above a magnet.

The action of a magnet upon a needle is greatly simplified when the needle is so small that its two poles may be considered as coincident; in which case the difference between the action of any one pole of a magnet upon them will be infinitely small. When this is the case, the directive force of the magnet upon the small needle must be very considerable, while the attractive force, measured by the difference of the action on the two poles, is nothing. Hence it is that alone which is concerned in the arrangement of minute needles or particles subjected to the action of a magnet.

An investigation of the force of the magnetic curves was made by Professor Playfair, at the request of Professor Robison. Professor Leslie afterwards undertook the same investigation;[1] and Dr Roget[2] more recently gave a more simple demonstration of the two fundamental propositions respecting them, and described an instrument which he invented for the mechanical description of these curves. Playfair's investigation, which is sufficiently simple, is as follows; the only change which we have made upon it being the substitution of the second power of the distance for the *m*th power as used by him.

PROP. Two magnetical poles being given in position, the force of each of which is inversely as the square of the distance from it, it is required to find a curve, in any point of which a needle (indefinitely short) being placed, its direction, when at rest, may be a tangent to the curve.

"1. Let A and B be the poles of a magnet, C any point in the curve required; then we may suppose the one of these poles to act on the needle only by repulsion, and the other only by attraction, and the direction of the needle when at rest will be the diagonal of a parallelogram the sides of which represent these forces. Therefore, having joined AC and BC, let AD be drawn parallel to BC, and make $\frac{1}{AC^2} : \frac{1}{BC^2} = AC : AD$; join CD, then CDF will touch the curve in C.

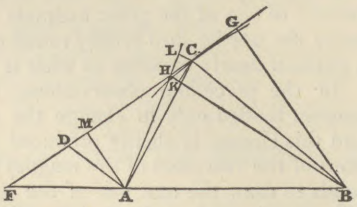

Fig. 47.

"2. Hence an expression for AF may be obtained; for, by the construction, $AD = \frac{AC^3}{BC^2}$; and since $BC : AD = BF : FA$, and $BC - AD : AD = AB : AF$, we have $AF = \frac{AB \times AC^3}{BC^3 - AC^3}$.

"3. A fluxionary expression for AF may also be found in terms of the angles CAB, ABC. In CF take the indefinitely small part CH; draw AH, BH, and from C draw CL perpendicular to AH, and CK to BH; draw also BG and AM at right angles to FH. Let the angles CAB $= \phi$ and CBA $= \psi$, then CAH $= \dot{\phi}$ and CBH $= -\dot{\psi}$; also $CL = AC \times \dot{\phi}$, and $CK = -BC \times \dot{\psi}$. Now $HC : CL = AC : AM = \frac{AC^2 \times \dot{\phi}}{HC}$; and for the same reason $BG = -\frac{BC^2 \times \dot{\psi}}{HC}$. Therefore, since $AF : FB = AM : BG$, we have $AF : FB = \frac{AC^2 \times \dot{\phi}}{HC} : -\frac{BC^2 \times \dot{\psi}}{HC}$, and $AF : AB = \sin \dot{\psi}^2 \dot{\phi} : -\sin \psi^2 \dot{\phi} - \sin \phi^2 \dot{\psi}$; wherefore, if $AB = a$, $AF = \frac{-a\dot{\phi} \sin \dot{\psi}^2}{\dot{\psi} \sin \varphi^2 + \dot{\phi} \sin \psi^2}$.

"4. If this value of AF be put equal to that already found, a fluxionary equation will be obtained, by the integration of which the curve may be constructed. Because $AF = \frac{AB \times AC^3}{BC^3 - AC^3}$; and since $AC = \frac{a \sin \psi}{\sin (\dot{\phi} + \psi)}$, and

$$BC = \frac{a \sin \phi}{\sin (\phi + \psi)}, \text{ we have by substitution}$$

$$AF = \frac{a \sin \psi^3}{\sin \phi^3 - \sin \psi^3} = -\frac{a \dot{\phi} \sin \psi^2}{\dot{\psi} \sin \phi^2 + \dot{\phi} \sin \psi^2}.$$

Hence $\sin \phi^2 \times \dot{\psi} \sin \psi^3 + \dot{\phi} \sin \psi^5 = -\sin \psi^2 \times \dot{\phi} \sin \phi^3 + \varphi \sin \psi^5$, and therefore $\dot{\psi} \sin \psi + \dot{\varphi} \sin \varphi = 0$, and $\cos \varphi + \cos \psi = C$.

"5. Hence, if, besides the points A and B, any other point be given in the curve, the whole may be described. For instance, let the point E be given in the curve, and in the line DE which bisects AB at right angles. Describe from the centre A a circle through E, viz. QER; then AD be-

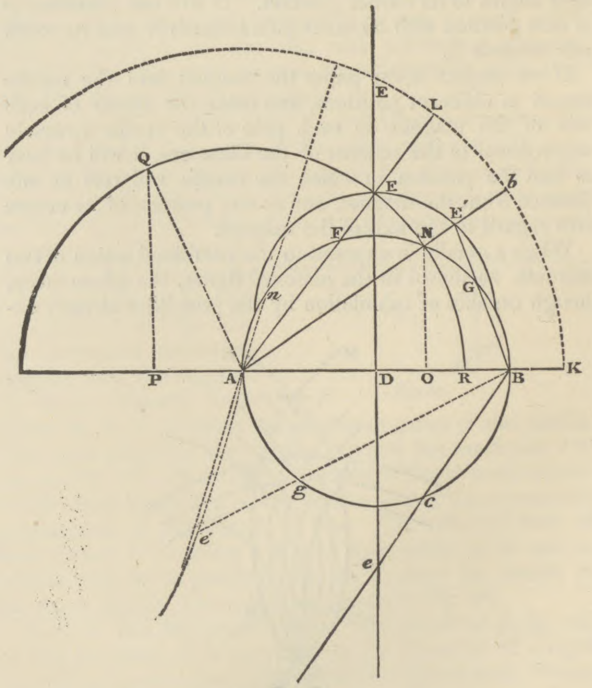

Fig. 48.

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[1] *Geometrical Analysis.*

[2] *Journal of the Royal Institution of Great Britain,* vol. i., p. 311. Feb. 1831.

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ing the cosine of DAE to the radius AE, the sum of the cosines of $\varphi \times \psi$ will be everywhere (to the same radius) = 2 AD = AB. Therefore, to find E′, the point in which any other line AN, making a given angle with AB, meets the curve, draw from N, the point in which it meets the circumference of the circle QER, NO perpendicular to AB, so that AO may be the cosine of NAO, and from O toward A take OP = AB, then AP will be the cosine of the angle ABE′; so, to find BE′, draw PQ perpendicular to AP, meeting the circle in Q; join AQ and draw BE′ parallel to AQ, meeting AE′ in E′; the point E′ is in the curve. In this way the other points of the curve may be found.

"The curve will pass through B, and will cut AB at an angle of which the cosine = RB. If then E be such that AE = AB, the curve will cut AB at right angles. If E″ be more remote from A, the curve will make with AB an obtuse angle toward D; in other cases it will make with it an acute angle.

"A construction somewhat more expeditious may be had by describing the semicircle AFB, cutting AE in F, and AE′ in N, and describing a circle round A with the distance AL = 2 AF, cutting AE′ in *b*. If BG be applied in the semicircle AFB = N*b*, BG must cut AN in a point E′ of the curve, because AN + BG = 2 AF, and AN and GB are cosines of the angles at A and B.

"As the lines AN and BG may be applied either above or below AB, there is another situation of their intersection E′. Thus A*n* being applied above, and B*g* below, the intersection is in *e*′. The curve has a branch extending below A; and if D*e* be made = DE, and B*e* be drawn, it will be an asymptote to this branch. There is a similar branch below B. But these portions of the curve evidently suppose an opposite direction of one of the two magnetic forces, and therefore have no connection with the position of the needle."[1]

The general form of the magnetic curves is shown in fig. 49, where they are seen *converging* to the two poles N, S of the magnet NS, and changing their form with their distance from the magnet.

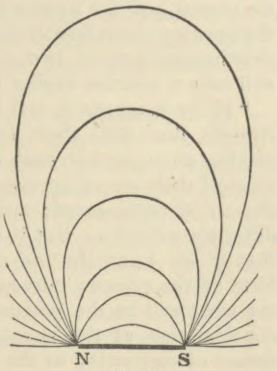

Fig. 49.

We have already stated that iron filings, arranged by the action of a powerful magnet, afford the finest experimental illustration of the magnetic curves. The best way to do this is to stretch a sheet of paper tightly over a wooden frame, and place it horizontally immediately above a powerful bar magnet lying on the table. Fine iron filings are now to be shaken through a gauze bag upon the surface of the paper. When the filings are thrown into a state of agitation by gently tapping upon the paper frame, they will dispose themselves into regular lines, stretching from one pole of the magnet to the other, and following the course of the magnetic curves, and exhibiting them beautifully to the eye. This effect is shown in the annexed figure 50, where N, S are the poles of the magnet NS, *mn* being the mean line where no filings adhere. The same arrangement is also produced when the magnet is held above the paper containing the filings.

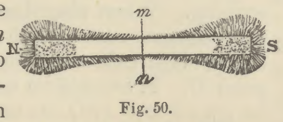

Fig. 50.

In the case of induced magnetism, the steel filings arrange themselves in curves round the iron on which the magnetism is induced, as shown in fig. 51, where the small bar of iron is in contact with the north pole N of a magnet, *mn* being the mean line which separates the two opposite actions of the little iron bar. When the little bar of iron is placed at a distance from the magnet N, as in fig. 52, the filings arrange themselves as in that figure, *mn* being the mean line as before.

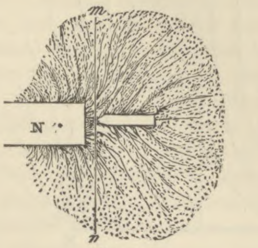

Fig. 51.

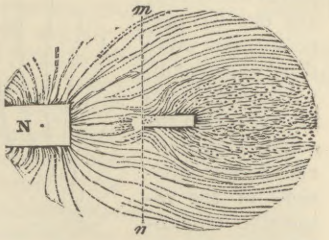

Fig. 52.

Dr Roget gives the following interesting account of the phenomena which take place by continuing to agitate the filings when they are arranged, as in fig. 53:—

"By continuing to tap upon the paper," says he, "the filings arrange themselves still more visibly into separate lines; but here a curious and perhaps unlooked-for phenomenon presents itself. The lines gradually move and recede from the magnet, appearing as if they were repelled instead of attracted, as theory would lead us to expect. This arises from the circumstance, that each particle of iron, or cluster of particles, is thrown up into the air by the shaking of the paper, and, while unsupported, immediately turns on its centre, and acquires a position more or less oblique to the plane of the paper. This is shown in fig. 53, in which M represents a section of the magnet, PP a section of the paper, and *ff* the position of the filaments of iron thrown up into the air. The end of each filament nearest to the magnet is thus turned a little downwards, and the filament falls upon the paper at a point a little more distant than that which it before occupied; and thus, step by step, it moves farther and farther from the magnet, till it reaches the edge of the paper, and falls off.

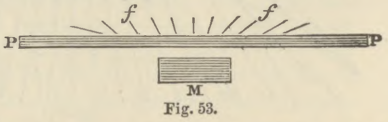

Fig. 53.

"When the magnet, instead of being beneath the paper, is held above it, the effect is just the reverse. In this latter case, the lower ends of the filaments having a tendency to turn towards the magnet, the filings gradually collect under it, when made to dance by the vibrations of the paper, instead of falling outwards as they did before. This will be seen from fig. 54, where the letters have the same indications as in fig. 53."[2]

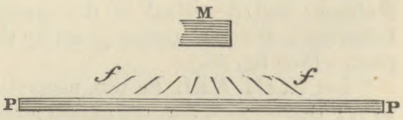

Fig. 54.

A different set of magnetic curves is produced when two similar poles, for example, two north poles, as shown in fig. 55, are placed near each other. These curves are called *divergent* curves, and may be exhibited by iron filings like the convergent ones.

Dr Roget has given the following expeditious method of delineating a great number of magnetic curves, related to the same distance between two magnetic poles. He describes from each pole N, S, fig. 56, as centres, the equal circles or semicircles AA, BB, with as large a radius as the paper will allow; and dividing the axis produced till

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[1] Robison's *Mechanical Philosophy*, vol. iv., p. 350-3.

[2] *Library of Useful Knowledge*, art. *Magnetism*, p. 21.

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it meets both circles, he marks off, on the circumferences of both circles, the points where they are cut by perpendiculars from these points of division; then drawing radii from the centre of each circle to the divisions of the respective circumferences, the mutual intersections of these radii will give different sets of points indicating the form of the magnetic curves which pass through them. These curves are, in the present case, composed of a succession of diagonals of the lozenge-shaped interstices formed by the intersecting radii, as shown from *convergent* curves in the upper half of the figure. In the case of *divergent* curves in fig. 55, we must take the other diagonals of the lozenge-shaped intervals between the intersecting radii; that is, the diagonals which cross those constituting the convergent curves. This is shown in the lower half of the figure.

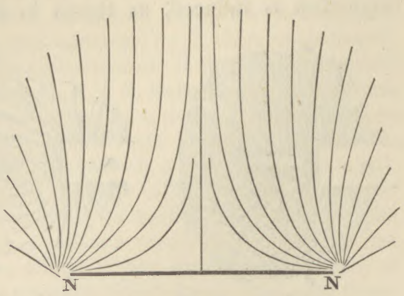

Fig. 55.

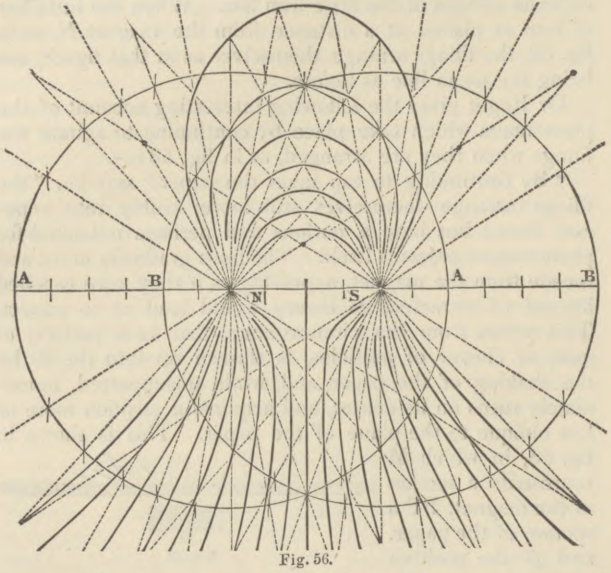

Fig. 56.

The curves which are formed when the north and south poles of two magnets are placed near each other, as in fig. 56, enable us to explain the phenomena discovered by Dr Robison, and described in the preceding section. The following is the explanation given by that eminent philosopher. (See fig. 46.)

"Let NHM, NEL, be two magnetic curves, belonging to A; that is, such that the needle arranges itself along the tangent of the curve. Then the magnet B has two curves SGK, SEI, perfectly equal, and similar to the other two. Let the curves NHM and SGK intersect in C and F. Let the curves NEL and SEI touch each other in E.

"The needle being placed at C, would arrange itself in the tangent of the curve KGS, by the action of B alone, having its north pole turned towards the south pole S of B. But, by the action of A alone, it would be a tangent to the curve NHM, having its north pole turned away from N. Therefore, by the combined action of both magnets, it will take neither of these positions, but an intermediate one, nearly bisecting the angle formed by the two curves, having its north pole turned toward B.

"But remove the needle to F. Then, by the action of the magnet A, it would be a tangent to the curve FM, having its north pole toward M. By the action of B, it would be a tangent to the curve KFG, having its north pole in the angle MFG, or turned toward A. By their joint action, it takes a position nearly bisecting the angle GFM, with its north pole toward A. Let the needle be placed in E. Then, by the action of the magnet A, it would be a tangent to the curve NEL, with its north pole pointing to F. But, by the action of B, it will be a tangent to SEI, with its north pole pointing to D. These actions being supposed equal and opposite, it will have no verticity, or will be neutral, and retain any position that is given to it.

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"The curve SEI intersects the curve NHM in P and Q. The same reasoning shows that when the needle is placed at P, it will arrange itself with its north pole in the angle SPH; but, when taken to Q, it will stand with its north pole in the angle EQM.

"From these facts and reasonings we must infer, that, for every distance of the magnets A and B, there will be a series of curves, to which the indefinitely short needle will always be a tangent.

"They will rise from the adjoining poles on both sides, crossing diagonally the lozenges formed by the primary or simple curves, as in fig. 46. These may be called compound or secondary magnetic curves. Moreover, these secondary curves will be of two kinds, according as they pass through the first or second intersections of the primary curves, and the needle will have opposite positions when placed on them. These two sets of curves will be separated by a curve GEH, in the circumference of which the needle will be neutral. This curve passes through the points where the primary curves touch each other. We may call this *the line of neutrality*, or inactivity.

"We now see distinctly the effect of bringing the magnets A and B nearer together, or separating them farther from each other. By bringing them nearer to each other, the point E, which is now a point of neutrality, may be found in the *second* intersection (such as F) of two magnetic curves, and the needle will take a sub-contrary position. By drawing them farther from each other, E may be in the *first* intersection of two magnetic curves, and the needle will take a position similar to that of C.

"If the magnets A and B are not placed so as to form a straight line with their four poles, but have their axes making an angle with each other, the contacts and intersections of their attending curves may be very different from those now represented; and the positions of the needle will differ accordingly. But it is plain from what has been said, that if we knew the law of action, and consequently the form of the primary curves, we should always be able to say what will be the position of the needle. Indeed, the consideration of the simple curves, although it was the means of suggesting to the writer of this article the explanation of those more complicated phenomena, is by no means necessary for this purpose. Having the law of magnetic action, we must know each of the eight forces by which the needle is affected, both in respect of direction and intensity; and are therefore able to ascertain the single force arising from their composition.

"When the similar poles of A and B are opposed to each other, it is easy to see that the position of the needle must be extremely different from what we have been describing. When placed anywhere in the line DF, between two magnets, whose north poles front each other in N and S, its north pole will always point away from the middle point D. There will be no neutral point E. If the needle be placed at P or Q, its north pole will be within the angle EPH, or FQI. This position of the magnets gives another set of secondary curves, which also cross the primary curves passing diagonally through the lozenges formed by their intersection. But it is the other diagonal of each lozenge which is a chord to those secondary curves. They

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will therefore have a form totally different from the former species."

CHAP. IX.—ON TERRESTRIAL MAGNETISM.

We have already seen, in preceding chapters, that a magnetic bar or needle, when either suspended by a thread, or at liberty to move freely upon a pivot, will, when all other magnetic bodies are entirely removed from it, settle in a fixed position, which, in this country, is about 25° to the W. of N.; this deviation of the needle from the N. is called its *variation* or *declination.* The very same thing will take place if a magnet or magnetized needle is placed on a piece of cork, and made to float on any fluid surface. The magnetic force by which the magnetic needle is thus made to take a fixed direction, and to return to it when it is pushed aside from that direction, has been naturally supposed to reside in the earth, and hence it has been called *terrestrial magnetism.*

But not only is a magnetized body *directed* in this manner by some unseen power; an unmagnetized body, such as a piece of iron, may be rendered permanently magnetic by the same power. This phenomenon is said to have been first observed in the vertical rod of the weather-cock of the church of the Augustines at Mantua, though others have ascribed the discovery of the fact to Gassendi. This rod had become magnetized by the continued action of the invisible power of which we speak. In later times it has been observed, that a bar of soft iron is, by the influence of the same power, converted into a temporary magnet, with a N. and S. pole, when it is placed in the direction which a magnetic needle assumes, and is inclined to the horizon.

If, in place of suspending the needle, or making it move horizontally on a pivot, we take an unmagnetized needle, and balance it upon a horizontal axis, then it will of course lie horizontally; but if we magnetize the needle, we shall find that it no longer remains horizontal, but takes an inclined position, or *dips*, as it is called; the *dip*, or the *inclination* downwards from a horizontal line, being about 70° in this country.

If we now take a magnetic needle, and suspend it by a silk fibre, we shall find that when it is pushed out of its position of rest, it will perform a certain number of oscillations in a given time before it again takes a fixed position. When this observation is made in different latitudes, it is found that the needle is brought to rest sooner in some places than in others; which proves that the intensity or strength of the magnetic force which directs the needle to the N. varies in different latitudes. Hence we have to consider three important classes of phenomena in reference to *terrestrial magnetism.*

1. The variation or declination of the needle, and its laws.
2. The dip or inclination of the needle.
3. The intensity of terrestrial magnetism; of which we shall treat as perspicuously and fully as the nature of the subject and our confined limits will permit.

SECT. I.—*On the Variation or Declination of the Needle.*

Variation of the needle.

A general account of the phenomena of the variation of the needle has been given in the order of their discovery in the historical part of this article. We shall now proceed to give a more minute account of them.

Measures of the variation of the needle have been taken by navigators and travellers in every part of the globe. Setting aside the inaccuracies common to them all, arising from the imperfect instruments which were in many cases employed, the observations made on shipboard were particularly liable to error, owing to the action which the iron on board exercised upon the compass.

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Halley.

The first person who attempted to collect and generalize the immense number of observations which had been made on the variation of the needle was Dr Halley, who published them in a sea-chart in 1700, in which he traced lines through all the parts of the globe where the variation was 0°, 5°, 10°, &c. These lines, which have since been called *Halleyan lines* or *curves*, excited great interest, and had the advantage of giving, at one glance, an ocular picture of the phenomena in every part of the world. As this *Variation Chart*, however, soon became old, from the rapid changes in the variation, as well as from confused methods of observation, Messrs Mountain and Dodson collected, from the records of the Admiralty, and from the papers of various naval officers, about 50,000, which they laid down in variation charts for 1745 and 1756.

Churchman.

The next step in the generalization of the phenomena of variation was made by Mr Churchman, who published in 1794 a programme of a *Magnetic Atlas.* He refers his variation lines to two poles, one of which he places, for the year 1800, in Lat. 58° N., and Long. 134° W. of Greenwich, very near Cape Fairweather; while the other pole is in Lat. 58° S., and Long. 165° E. of Greenwich. He supposes the northern pole to revolve in 1096 years, and the southern one in 2289 years.

Hansteen.

It is to Professor Hansteen, however, that we are indebted for the most satisfactory collection of observations on the variation of the needle, and for the most philosophical generalization of them. In the *Magnetic Atlas* which accompanies his work on the magnetism of the earth, he has published a variation chart for 1787, in which the irregularities and inflexions of the curves, and their total want of symmetry, prove how irregular are the causes on which terrestrial magnetism depends. In this chart the *western line of no variation*, or that which passes through all the places on the globe where the needle points to the true N., begins in Lat. 60°, to the W. of Hudson's Bay, proceeds in a S.E. direction through the North American lakes, passes the Antilles and Cape St Roque, till it reaches the South Atlantic Ocean, where it cuts the meridian of Greenwich in about 65° of S. Lat. This line of no variation is extremely regular, being almost straight till it bends round the eastern part of South America, a little S. of the equator. The *eastern line of no variation* is exceedingly irregular, being full of loops and inflexions of the most extraordinary kind, indicating the action of local magnetic forces. It begins in Lat. 60° S., below New Holland, crosses that island through its centre, extends through the Indian Archipelago with a double sinuosity, so as to cross the equator three times, first passing N. of it to the E. of Borneo, then returning to it and passing S. between Sumatra and Borneo, and then crossing it again beneath Ceylon, from which it passes to the E. through the Yellow Sea. It then stretches along the coast of China, making a semicircular sweep to the W., till it reaches the Lat. of 71°, where it descends again to the S., and returns northwards with a great semicircular bend, which terminates in the White Sea. These lines of no variation are accompanied through all their windings by other lines where the variation is 5°, 10°, 15°, &c.; these last lines becoming more irregular as they recede from those of no variation. In the South Pacific Ocean, and the equatorial part of the North Pacific, they are so little dependent on the lines of no variation, that they form returning curves of an elongated oval form, the curves of 2°, 3°, 4°, 5°, 6°, and 7°, crossing the equator and the tropic of Capricorn twice, so that, in the centre or axis of the ovals which these lines form, there should be a fragment of a line of no variation.

His variation chart.

Barlow.

The great changes which had taken place in the variation since 1787, and the number of new observations which had been made in every part of the world, induced Professor Barlow, in 1833, to construct a new variation chart.[1]

Four magnetic poles of Hansteen.

In the charts both of Hansteen and Barlow the variation lines exhibit a convergency at their extremities;[2] and Hansteen considers it proved that there are *four points of convergency*, two in each hemisphere, a weaker and a stronger, on opposite sides of the poles of revolution. These four points he considers as the *four magnetic poles* of the globe; and, by comparing observations which have been made at different times, he concludes that they have a regular motion round the globe, the two northern ones from W. to E., in an oblique direction, and the two southern ones from E to W., also obliquely. The following are the periods of their revolution, as calculated from the best observations previous to 1817, when his work was published:—

The *strongest* NORTH pole in 1740 years.
The *strongest* SOUTH pole in 4609 years.
The *weakest* NORTH pole in 860 years.
The *weakest* SOUTH pole in 1304 years.

Upon these data he computed the following table, showing the position of these poles from 1800 to 1850:—

Years.	Strongest North Pole.		Strongest South Pole.		Weakest North Pole.		Weakest South Pole.	
	West Longitude.	North Latitude.	East Longitude.	South Latitude.	East Longitude.	North Latitude.	West Longitude.	South Latitude.
1800	93° 33′	69° 53′	134° 8′	69° 7′	131° 43′	85° 25′	130° 28′	77° 50′
1810	91 28	69 45	133 21	68 59	135 54	85 18	133 14	78 3
1820	89 24	69 38	132 35	68 52	140 6	85 12	135 59	78 16
1830	87 19	69 30	131 47	68 44	144 17	85 6	137 45	78 29
1840	85 15	69 22	131 1	68 37	148 28	85 0	140 31	78 41
1850	83 10	69 14	130 14	68 29	152 40	85 0	143 16	78 54

Hansteen remarks, that the four periods above mentioned, viz., 860, 1304, 1740, and 4609, become, by a slight alteration, 864, 1246, 1728, and 4320; and he adds, rather fancifully for a matter of science, that these numbers are equal to 2 × 432, 3 × 432, 4 × 432, and 10 × 432, and that the number 432 is one of the most important among the sacred numbers of the Indians, Babylonians, Greeks, and Egyptians, which are said to depend on certain combinations of natural events. According to the mythology of the Brahmins, the duration of the world is divided into four periods; the first of which is 432,000 years; the second, 2 × 432,000; the third, and so in all $(1+2+3+4) = 10 \times 432{,}000$. Hansteen also considers it worthy of remark, that the sun's mean distance from the earth is 216 (the half of 432) radii of the sun, the moon's mean distance 216 radii of the moon, and, what he says is still more striking, $60 \times 432 = 25920$, the smallest number divisible at once by all the four periods; and hence, he adds, the shortest line in which all the four poles can accomplish a cycle, and return to the same state as at present, *coincides exactly with the period in which the precession of the equinoxes will amount to a complete circle*, reckoning the precession at a degree in 72 years.

Hansteen considers the four poles as originating in *two* magnetic axes, the two strongest being the termination of one axis, and the two weakest, of the other; and he conceives that they may have been produced either along with the earth itself, or at a later epoch. According to the first supposition, it is not easy to account for their change of position; but according to the last, they must have originated either from the earth alone, or from some external cause. If they originated in the earth, their change of position is still unsusceptible of explanation; and hence Hansteen conceives that they have their origin from the action of the sun heating and illuminating the earth, and producing a magnetic tension, as it produces electrical phenomena.

After the publication of Professor Hansteen's work, the valuable observations made during the British voyages of discovery in the arctic regions were given to the world; and by availing himself of these, and obtaining access to others unpublished in the marine chart office at the Admiralty, the Norwegian philosopher obtained more accurate determinations both of the positions and periods of revolution of the magnetic pole. The following is a brief abstract of his calculations:—

1. *Strongest North Pole.*—In 1813 the observations made on board H.M.S. Brazen, in Hudson's Bay, give 67° 10′ for the latitude of the strongest north magnetic pole, and 92° 24′ for its west longitude. Hence, by comparing this with previous determinations, we have—

	Latitude of Pole.	West Longitude of Pole.
1730	70° 45′	108° 6′
1769	70 17	100 2
1813	67 10	92 24

From these data we obtain the motion of the pole to the E.

Epochs.	Years.	Change of Place in Longitude.	Annual Motion.
From 1730 to 1769	39	8° 4′	12′ 44″
1769 to 1813	44	7 38	10 41

From which we obtain—

Mean annual motion of the pole	11′ 4″·25
Period of complete revolution	1890 years.

In August 1819, Captain Parry was to the N. of this pole, and found the dip to be 88° 37′, and on the 11th September he was three degrees W. of the pole. Hence, as his latitude was then 74° 27′, the latitude of the pole must have been about 71° 27′.

According to the more recent observations of Commander Ross, this pole, upon which he erected a flag, is situate in north latitude 70° 5′ 17″, and west longitude 96° 45′ 48″, which coincides strikingly with Hansteen's result. According to the survey of Lieut.-Col. Lefroy in 1843 and 1844, this pole was situate in north latitude 52° 19′, and west longitude 92°. Its force was 1·88 in the arbitrary, and 14·2 in the absolute scale. Hence the attractive forces at the strongest and weakest north poles are as 14·2 to 13·3, or nearly as 107 to 100.

2. *Strongest South Pole.*—By combining the observations of Cook in 1773 and 1777, with those of Furneaux in 1773, and comparing these with Tasman's observations in 1642, Hansteen has found the following position of it:—

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[1] See *Philosophical Transactions*, 1833, pp. 667-675, and plates xvii. and xviii.

[2] Professor Barlow remarks that the very spot where Sir James Ross found the needle perpendicular, "that is, the pole itself, is precisely that point in my globe and chart in which, by supposing all the lines to meet, the several curves would best preserve their unity of character, both separately and conjointly, as a system."

	Motion in 131 Years.
1642, N. Lat. 71° 5′; E. Long. 146° 57′.........	10° 14′
1773, N. Lat. 69° 26′ 5″; E. Long. 136° 15′ 4″	

Hence the real motion of this pole in 131 years is 10° 14′ or 4′·67 annually, and its period of complete revolution will be 4605 years.

3. *Weakest North Pole.*—By comparing observations made in 1770 and 1805, at Tobolsk, Tara, and Udinsk, in Siberia, Professor Hansteen found—

	North Latitude.	East Longitude.	Motion in 35 Years.	Annual Motion.
1770	85° 46′	91° 29′ 30″	14° 35′	35′·128
1805	85 21½	116 19		

Hence this pole completes its revolution from E. to W. in 860 years. By the observations of Hansteen in 1828–9 this pole is in east longitude 120°, its force in the arbitrary scale 1·76, and in the absolute scale 13·3.

4. *Weakest South Pole.*—By comparing observations made by Cook and Furneaux in 1774, with those recorded by Halley as made in 1670, Hansteen obtained the followin results:—

	South Latitude.	West Longitude.	Motion in 104 Years.	Annual Motion.
1670	64° 7′	94° 33½′	28° 43½′	16′·57
1774	77 17	123 17		

Hence this pole completes its revolution from E. to W. in 1303 years.

The Rev. Mr Grover has recently endeavoured to show "that the movement of the magnetic pole governing Europe is capable of recognition, and that it possesses an orbitual character, the general features of which can be distinctly traced." The form of the magnetic orbit which he has deduced from a careful examination of authentic observations made at London, Paris, and St Petersburg, is shown in the annexed figure, where N is the true north pole, in the middle of a section of the northern hemisphere, and the irregular elliptical curve the path of the pole, so far as hitherto observed. The place of the pole at different times between 1580 and 1846 are marked on the curve. The isodynamic poles, or those to which the lines of equal magnetic intensity converge, as shown in fig. 62, are marked by the letters A and S. In the course of his investigation, Mr Grover has noticed a certain acceleration and retardation of the motion, and the opposite bias of the two isodynamic hemispheres, and deduces some curious facts explanatory of the ovals, loops, and singular curvatures of the magnetic lines. Mr Grover regards the ovals as produced temporarily from the peculiar position of the moving magnetic pole in relation to the isodynamic poles A and S, by which a bias is given to the needles of a whole district.

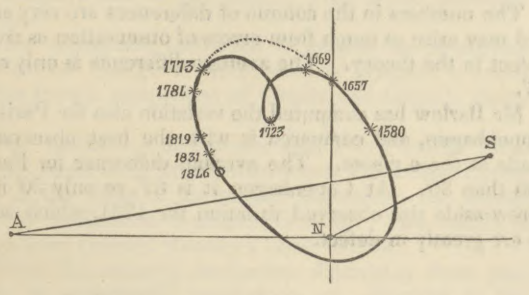

Fig. 57.

Professor Barlow endeavoured to deduce the position of the magnetic pole, upon the supposition that the magnetic phenomena of the earth are analogous to those exhibited by a simple iron ball. The tangent of the dip being equal to double the tangent of the magnetic latitude, Mr Barlow supposes π to be the magnetic pole, N, S the terrestrial poles, and L a known place where the dip and variation have been well ascertained. Then by the dip we obtain the magnetic latitude πL; NL being the terrestrial latitude, and $NL\pi$ the variation. Hence, in the spherical triangle $NL\pi$, we have two sides and the contained angle to find the side $N\pi$ the terrestrial latitude of the magnetic poles, and πNL the longitude of the same pole, in reference to the meridian NL.

In making this computation, Mr Barlow selected a certain number of the best observations on the dip and variation of the needle, made in different parts of the world, and he obtained the following results :—

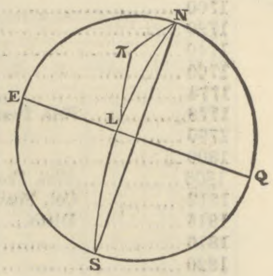

Fig. 58.

Place of Observation.	Date.	Dip.	Variation.	Computed Place of Magnetic Pole. N. Lat.	Computed Place of Magnetic Pole. W. Long.
Tristan d'Acunha..	1821	37°53′ S.	12° 0′ W.	70° 56′	49° 33′
Trinidad	1821	10 27 N.	5 0 W.	73 59	47 20
St Jago	1820	48 0 N.	15 55 W.	69 37	67 4
Teneriffe	1820	58 22 N.	20 47 W.	69 49	69 14
Madeira	1820	63 47 N.	23 7 W.	68 4	65 26
Madrid	1799	67 41 N.	19 59 W.	72 47	50 33
Paris	1814	68 36 N.	22 34 W.	75 31	67 4
London	1818	70 34 N.	24 30 W.	75 2	67 41
Berlin	1805	69 53 N.	18 2 W.	79 2	70 44
Copenhagen	1813	71 26 N.	18 22 W.	79 43	67 38
Davis' Straits	1820	83 43 N.	60 20 W.	67 37	94 26
Regent's Inlet	1820	88 26 N.	118 16 W.	71 10	98 16
Baffin's Bay	1820	84 30 N.	82 2 W.	71 13	97 3
Possession Bay......	1820	86 4 N.	108 46 W.	69 40	99 10
Melville Island......	1820	88 43 N.	127 46 E.	73 12	.102 46

Among these results there is a discrepancy of no less than 55° in longitude, and 10° in latitude; and hence Mr Barlow concluded that every place has its particular polarizing axis, which probably in all cases falls within the frigid zones, varying within these limits through all possible degrees of latitude and longitude.

These aberrations Mr Barlow ascribed to local inequalities in the distribution of the ferruginous parts of the terrestrial sphere.

In the last edition of this work we published extensive tables of the variation from observations collected by Hansteen, and communicated to us by himself. Although these tables must always be valuable, as containing important facts in terrestrial magnetism, yet so many new measures have been taken of the variation of the needle in all parts of the world, that a complete table of the latest results would be quite unsuited to a work like this.

General Sabine recently collected all the best observations, and published them graphically in his interesting *Map of the Lines of Equal Declination for the Epoch of* 1840.

On the progressive Changes in the Variation of the Needle.

Change in the variation.

We have already seen that the variation of the needle experiences a progressive change in every part of the globe. The following table shows very satisfactorily the change which has taken place in London :—

Table of the Variation at London from 1576 to 1831.

Years.	Observers.	Variations.	
1576................	Norman................	11° 15′	easterly.
1580................	Burroughs............	11 17	maximum.
1622................	Gunter	6 12	...
1634................	Gellibrand............	4 5	...
1657 1662	....	0 0	no variation.

Years.	Observers.	Variations.	
1666		0 34	westerly.
1670		2 6	...
1672		2 30	...
1700		9 40	...
1720		13 0	...
1740		16 10	...
1760		19 30	...
1774		22° 20′	
1778	*Phil. Trans.*	22 11	...
1790		23 39	...
1800		24 36	...
1806	*Phil. Trans.*	24 8	...
1813	Col. Beaufoy	24 20 17″	...
1815	Ditto	24 27 18	maximum.
1816		24 17 9	...
1820		24 11 7	...
1823		24 9 40	...
1831		24 0 0	...

The following table shows the progressive change in the variation of the needle at Paris:—

Table of the Variation at Paris from 1541 *to* 1829.

Years.	Variations.	Years.	Variations.
1541	7° 0′ easterly.	1683	3° 50′ westerly.
1550	8 0 ...	1700	7 40 ...
1580	11 30 maximum.	1750	17 15 ...
1603	8 45 ...	1767	19 16 ...
1618	8 0 ...	1780	20 35 ...
1630	4 30 ...	1785	22 0 ...
1640	3 0 ...	1800	22 12 ...
1659	2 0 ...	1807	22 34 ...
1664	0 40 ...	1814	22 54 ...
1669	0 0 no variation.	1819	22 29 ...
1667	0 15 westerly.	1824	22 23 ...
1670	1 30 ...	1829	22 12·5 Arago.
1680	2 40		

The following table shows the progressive change in the variation in the southern hemisphere since the time of Vasco de Gama:—

Table of the Variation at the Cape of Good Hope.

Years.	Variations.	Years.	Variations.
1605	0° 30′ easterly.	1724	16° 27′ westerly.
1609	0 12 westerly.	1752	19 0 ...
1614	1 30 ...	1768	19 30 ...
1667	7 15 ...	1775	21 14 ...
1675	8 30 ...	1791	25 40 maximum.
1702	12 50 ...	1804	25 4 ...

Professor Hansteen has explained these progressive changes in the variation of the needle by the motion of the four magnetic poles. Taking the variations at Paris for the northern hemisphere, he remarks that in 1580 the weak N. pole in Siberia was about 40° E. of Greenwich, or to the N. of the White Sea; while the strong American pole was about 136° W. of Greenwich, or 36° E. of Behring's Straits. The W. pole, therefore, lay *nearer* Europe than now, and the strong one *more remote*. Hence the action of the former predominated, and drew the needle eastward. But the *weak* pole now withdrew itself towards the Siberian Ocean, from Europe, and the *strong one* approached it. The action of the latter therefore predominated, and the needle turned westward till 1814, in which year it reached its greatest declination, and commenced its easterly course.

The explanation is equally satisfactory in reference to the southern hemisphere, and the variation at the Cape. In 1605 the *weak* S. pole was 76½° W. of Greenwich, and the *strong* S. pole about 150° E. of that meridian. The weak pole was, therefore, much *nearer* the Cape than now, while the stronger pole was *more remote* from it. The influence of the *weak* pole was therefore most powerful, so that the S. pole of the needle moved towards the W., and its N. pole more towards the E. But when the *weak* S. pole receded from the Cape, and the *strong* one approached it, the S. pole of the needle turned more and more towards the strong pole, and its declination became consequently more westerly.

Mr Barlow has therefore given the following rule for calculating the variation of the needle, on the supposition that the magnetic pole which governs the needle in London was in 1818 in N. Lat. 75° 2′, and W. Long. 67° 41′, and that its motion was uniform at the rate of 4° 14′ in *ten* years, the variation being 0°, or the pole being in the meridian of London, in 1660.

Rule.—To the co-tangent of half the angle πNL (see the last figure), add the constant log. 1·65642; find the angle of which the sum is the tangent, and call it arc (A). To the same co-tangent add the log. 0·03987, and find the arc of which the sum is the tangent, and call it arc (B).

Then B − A will be the variation or the angle πLN. The following comparison of the variations thus computed with actual observation is very interesting:—

Years.	Variations.		Differences.	Observers.
	Observed.	Computed.		
1660	0° 0′	0° 0′	0° 0′	Bond.
1670	2 30	2 44	0 14 +	Halley.
1690	6 0	7 59	1 59 +	Ditto.
1720	14 17	14 47	0 30 +	Graham.
1740	17 0	18 20	1 20 +	Ditto.
1750	17 48	19 47	1 59 +	Ditto.
1770	21 9	22 4	0 55 +	Heberden.
1780	23 17	22 54	0 23 −	Gilpin.
1790	23 39	23 33	0 6 −	Ditto.
1800	24 3	24 1	0 2 −	Ditto.
1810	24 11	24 18	0 7 +	Ditto.
1818	24 30	24 30	0 0	...

The numbers in the column of differences are very small, and may arise as much from errors of observation as from a defect in the theory. The average difference is only about 45′.

Mr Barlow has computed the variation also for Paris and Copenhagen, and compared it with the best observations made at these places. The average difference for Paris is less than 30′. At Copenhagen it is 37′, or only 20′ if we throw aside the observed variation for 1731, which seems to err greatly in defect.

On the Annual Variation of the Needle.

Annual variation. Cassini.

Besides the progressive changes in the declination of the needle, M. Cassini observed an *annual* change, depending on the position of the sun in reference to the equinoctial and solstitial points.

Between the months of *January* and *April* the magnetic needle recedes from the N. pole of the globe, so that its western declination increases.

From *April* to the beginning of *July*, that is, from the vernal equinox to the summer solstice, the declination diminishes, or the needle approaches the N. pole of the globe.

From the summer solstice to the vernal equinox, the needle, receding from the N. pole, returns to the W., so that in October it has nearly the same position as in May, and between October and March the western motion is smaller than in the three preceding months.

Hence it follows, that during the *three* months between the vernal equinox and the summer solstice, the needle retrogrades towards the E.; and during the following *nine* months its general motion is towards the W.

Arago.

This important subject particularly occupied the attention of M. Arago. Taking the mean declination of each day, or that of the maximum and minimum, and the mean declination of each month, he arranged in tables the mean monthly declinations at Paris from 1784 to 1788, and also those at London, near the equinoxes and solstices, from 1793 to 1805, as calculated from the observations of Mr Gilpin, and, by a comparison of the results, he found a maximum of declination towards the vernal equinox, and a minimum towards the summer solstice; but this difference was less at London than at Paris.

In comparing the observations of Cassini in 1786 with those of 1800, corresponding to the measures of Gilpin, M. Arago found that they do not differ from one another in their magnetical relations, but in one point. In 1786 the annual change of declination was nine minutes, whereas in 1800 it was scarcely a minute. Hence he observed, that the retrograde motion which the needle experiences between the vernal equinox and the summer solstice decreases at the same time with the general and annual motion towards the W.

At Salem, in Massachusetts, where observations were made in 1810 by M. Bowditch, the declination is W., and has diminished for a great number of years about 2 minutes annually. In examining these observations, M. Arago did not find any trace of the period of Cassini. The declination has never diminished between the vernal equinox and the summer solstice, but it gradually increases from April to August. This increase is compensated by a decrease of the declination between September and December, so that the period seems to be transferred from spring to autumn. M. Arago conceived that if this idea should be found correct, the annual changes would be regulated by the following principles:—

1. When the needle, having a westerly declination, recedes from the meridian, it experiences a retrograde motion, which brings it back to this place. This is the discovery of Cassini.

2. This retrograde oscillation is greater in proportion as the annual change of declination is greater; a result deducible from a comparison of Cassini and Gilpin's observations.

3. The oscillation disappears, and every month gives nearly the same mean declination, when, the needle having arrived at the limit of its western digression, the annual change of declination becomes nothing. This result is deduced from Colonel Beaufoy's observations.

4. When the westerly declination diminishes from year to year, no remarkable oscillations are observed in the needle towards the E., excepting between the months of September and December. This is the observation of Mr Bowditch. According to Colonel Beaufoy's observations, the daily variation is greatest in *June* and *August*, and less in July, so that the annual curve has two *maxima* and two *minima* in the course of the year, the two maxima being in June and August, and the two minima in December and July.

On the Diurnal Variations of the Needle.

Diurnal variation.

That there is a daily change in the variation of the needle, as originally discovered by Mr Graham in 1724, has been placed beyond a doubt by observations made with the most accurate instruments in almost every part of the world. The following table contains the mean diurnal changes in the variation, according to the observations of Canton in 1759, of Gilpin in 1787 and 1793, and of Colonel Beaufoy in 1817-19.

Table of the Mean Daily Changes in Variation.

Months.	Observations of Canton. 1759.	Observations of Gilpin.		Colonel Beaufoy.
		1787.	1793.	1817-18-19.
January	7′ 8″	10′ 2″	4′ 3″	5′ 3″
February	8 58	10 4	4 6	6 3
March	11 17	15 0	8 5	8 22
April	12 26	17 4	11 7	11 48
May	13 0	18 9	10 4	9 53
June	13 21	19 6	12 6	11 15
July	13 14	19 6	12 5	10 43
August	12 19	19 4	12 1	11 26
September	11 43	15 5	9 8	9 44
October	10 36	14 3	7 0	8 46
November	8 9	11 1	3 8	7 10
December	6 58	8 3	3 8	4 7
Mean daily change	10 43	14 39	8 0	9 32

The following ranges in the variation for every month were obtained by Dr Lloyd from the Dublin observations during the years 1840–43.

Summer Half-Year.			Winter Half-Year.		
Month.	Westerly movement.	Easterly movement.	Month.	Westerly movement.	Easterly movement.
	Min.	Min.		Min.	Min.
April	13·3	11·6	October	7·8	9·7
May	12·2	8·4	November	4·8	7·0
June	12·3	9·2	December	3·9	6·6
July	11·6	9·2	January	5·2	7·6
August	11·8	10·2	February	6·8	8·1
September	10·1	10·8	March	9·7	10·5
Mean	11·9	9·9	Mean	6·4	8·3

It is remarkable, as noticed by Dr Lloyd, that the mean ranges of the easterly movements for the entire year are precisely equal, the mean value of each being 9′·1

Dr Lloyd has shown, from the Dublin observations, that the curves representing the annual variations in the declination of the needle, and in the temperature of the air, present the most complete accordance, not only as to the hours of *maxima* and *minima*, but in their entire course. Mr Horner obtained the same result from the Stockholm observations.[1]

Dr Lloyd has obtained the following measures of the secular variation:—

Year.	Variation.	Difference.
	Deg. Min.	Min.
1840	332 30·69	...
1841	332 34·65	+31·96
1842	332 43·55	+ 8·90
1843	332 50·10	+ 6·55
1844	332 53·43	+ 3·33
1845	332 59·75	+ 6·32
1846	333 7·22	+ 7·47

The variation is here measured from the N. *eastward.*

From these results Dr Lloyd concludes that the N. end of the magnet moves to the *east* from year to year, and that the westerly variation diminishes by 6′·06 annually in its mean quantity.

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[1] *Transactions of the Royal Irish Academy*, vol. xxii., part 1, 1849.

The following Table shows the Amount of the Daily Variation at other places compared with that at London.

London, general mean	60′	44″	
Geneva	15	42	Saussure.
Chamouni	17	6	
Col du Geant	15	43	
Freiberg	12	11·9	
Petersburg	12	10·1	
Nicolaeff	10	53·4	
Kasan	70	36·5	

When the diurnal variation of the needle was first discovered, it was supposed to have only two changes in its movements during the day. About seven A.M. its N. end began to deviate to the W., and about two P.M. it reached its maximum westerly deviation. It then returned to the eastward to its first position, and remained stationary till it again resumed its westerly course in the following morning. When magnetic observations became more accurate, it was found that the diurnal movement commences much earlier than seven A.M., but its motion is to the E. At half-past seven A.M. it reaches its greatest easterly deviation, and then begins its movement to the W. till two P.M. It then returns to the eastward till the evening, when it has again a slight westerly motion; and in the course of the night, or early in the morning, it reaches the point from which it set out twenty-four hours before. The most accurate observations made in England were those of Colonel Beaufoy, when the variation was about 24½′ W. In these the absolute maxima were earlier than in Canton's observations, and the second maxima W. about eleven P.M.

The following were the diurnal changes observed at Paris:—During the night it is nearly stationary. At sunrise its north extremity moves to the westward, as if it were avoiding the solar influence. Towards noon, or more generally from noon to three o'clock, it attains its maximum westerly deviation, and then it returns eastward till nine, ten, or eleven o'clock in the evening; and then having reached its original position, it remains stationary during the night. The amount of this daily variation is, for April, May, June, July, August, and September, from 13′ to 15′; and for the other six months of the year, from 8′ to 10′. On some days it rises to 25′, and on others it does not exceed 5′ or 6′.

According to M. Dove, the maximum easterly deviation of the needle takes place at eight A.M. at Freiberg, Nicolaeff, and St Petersburg, and at nine A.M. at Kasan; and the maximum of westerly deviation at two P.M. at Kassan, Nicolaeff, and St Petersburg, and at one P.M. at Freiberg.

In the northern regions, such as Denmark, Iceland, and Greenland, the diurnal variations are greater, and less regular. The needle is not stationary during the night, and it does not reach its maximum westerly deviation till between eight and ten P.M., and its most easterly about nine or ten A.M.

In advancing from the N. to the magnetic equator, the diurnal variation diminishes in amplitude, and it ceases to be perceptible in the magnetic equator. Captain Duperrey, however, found that when the place is either under the magnetic equator, or at a little distance from it, the N. point of the needle advances every morning to the *west* or to the *east*, according as the sun passes to the *north* or to the *south* of the place of observation.

In the southern magnetic hemisphere the daily variation takes place in an opposite manner, the *north* end of the needle moving to the E. at the same hours that it did to the W. in the northern hemisphere; a result which was established by the observations of Mr J. Macdonald at St Helena, and at Fort Marlborough, in Sumatra.[1] M. Freycinet was led to the same result by observations made in the Isle of France, Timor, Rawak, Guham, Mowi, Port Jackson, and other places. At the Marianne and Sandwich Isles, in the northern hemisphere, the *north* point of the needle moves to the W., as in Europe, from eight A.M. till one P.M., though the variation there is easterly. At Timor, Rawak, and Port Jackson, to the S. of the equator, the N. point of the needle moves during the morning in an opposite direction; hence the observations made to the N. of the line agree with those in Europe, while those in the southern hemisphere, like those of Macdonald, exhibit an opposite motion. M. Freycinet found that the diurnal oscillations have a small amplitude between the tropics. At Rawak, only the fortieth of a degree S. of the equinoctial line, M. Freycinet found that the needle oscillated every day with an amplitude of 3′; so that it is the magnetic, and not the terrestrial, equator, as Duperrey afterwards found, which separates the zone of westerly from the zone of easterly diurnal variations.

Observations are still wanting to show whether or not the daily variations have the same direction in places where the variation is westerly and in those where it is easterly.

The dipping needle also undergoes, as will be afterwards seen, daily variations, but their amplitude is of less amount. There can be no doubt, as M. Pouillet observes, that a needle capable of moving in any given azimuth will experience daily changes; and that a needle moveable in every direction round its centre of gravity would describe every day a cone whose base would be an ellipse, or some other curve more or less elongated, in different parts of the earth.

Cause of the diurnal variation.

The sun is now universally allowed to be the cause of the diurnal variations of the needle. Canton ascribed them to the action of solar heat, having ascertained that heat tends to diminish the attractive powers of a magnet, and assuming that the direction of the needle was due to the resultant of all the magnetic forces of the terrestrial sphere. When the sun was to the eastward of the needle, the forces lying to the eastward suffered a diminution of power, in consequence of which the westerly force prevailed, and the N. end deviated to the W. When the sun, on the other hand, was to the westward of the needle, the power on that side diminished, and the needle returned again to the eastward. Canton, however, did not give any explanation of the morning easterly variation of the needle.

On the Irregular Motions of the Magnetic Needle as produced chiefly by the Aurora Borealis.

Irregular motions of the needle produced by the aurora borealis.

Besides the regular changes of an annual and diurnal nature to which the needle is subject, it is sometimes affected with sudden and extraordinary movements, to which Baron Humboldt has given the name of *magnetic storms* or *hurricanes*, during which the needle traverses with a shivering motion, and often oscillates several degrees on each side of its mean position.

These sudden and capricious motions have been most frequently observed during the existence of the *auroræ boreales*, and have therefore been ascribed to that cause. The influence of this meteor on the magnetic needle was first noticed by Wargentin in 1750. It was observed by Bergman and others; and Van Swinden remarks, that he seldom failed to observe auroræ boreales after any anomalous motion of the needle; and he always concluded that there must have been one at the time, though he did not see it. As needles made of other substances, such as copper or wood, have not been found to be affected, the action of the aurora cannot be considered as an electrical one.

The influence of the aurora on the needle was particu-

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[1] Made in 1794, 1795, and 1796; see *Philosophical Transactions.* Mr Macdonald observes, that the diurnal variations are sensibly less between the tropics than in Europe.

Terrestrial Magnetism.

Dr Dalton's observations.

larly studied by Dr Dalton, who has stated his views in his *Meteorological Observations and Essays*, published in 1793, in a dissertation of great ability, which has never received the notice which it merits. He has shown that the luminous beams of the aurora are parallel to the dipping needle; that the rainbow-like arches cross the magnetic meridian at right angles; that the broad arch of the horizontal light is bisected by the magnetic meridian; that the boundary of a limited aurora is half the circumference of a great circle crossing the magnetic meridian at right angles, the beams perpendicular to the horizon being only those on the magnetic meridian.

Dr Dalton has shown, from numerous observations, that the aurora exercises an irregular action on the magnetic needle; and he has deduced from these observations the following results:—

1. When the aurora appears to rise only about 5°, 10°, or 15°, above the horizon, the disturbance of the needle is very little, and often insensible.

2. When it rises up to the zenith, and passes it, there never fails to be a considerable disturbance.

3. This disturbance consists in an irregular oscillation of the horizontal needle, sometimes to the eastward and then to the westward of the mean daily position, in such sort that the greatest excursions on each side are nearly equal, and amount to about half a degree each at Kendal.

4. When the aurora ceases, or soon after, the needle returns to its former station.

Professor Hansteen's observations on the magnetical influence of the aurora are peculiarly interesting. He states that the extraordinary shivering movements of the needle are perhaps never exhibited except when the aurora is visible; and that this disturbance seems to operate at the same time in places the most widely separated. The extent of these movements may in less than twenty-four hours amount to five or five and a half degrees. In such cases, he adds, the disturbance is also communicated to the dipping needle; *and as soon as the crown of the aurora quits the usual place* (*the points where the dipping needle produced would meet the sky*), *that instrument moves several degrees forward*, and seems to follow it. After such disorders, he continues, the mean variation of the needle is wont to change, and not to recover its previous magnitude till after a new and similar disturbance. During the continuance of the aurora borealis, the intensity of the earth's magnetic force seems to grow weaker; for which reason the needle recedes from that magnetic pole where the ray of the aurora is displayed.

The influence of the aurora borealis on the needle was studied with particular care by M. Arago, whose accurate and regularly continued series of observations on the daily changes of the magnetic needle at Paris enabled him to compare these changes with the occurrence of the northern light. The following is an abstract of his views on the subject:—The appearance of an aurora causes the magnetic needle to vary several degrees to the E. and W. of its mean position. In the region where it appears, luminous beams, differently coloured, shoot up from all points of the horizon; *and the part of the heavens where all these beams or radiations unite is precisely that to which a magnetic needle directs itself when suspended by its centre of gravity.* M. Arago also showed that the concentric circles, which become visible almost always before the luminous beams, rest each upon the two points of the horizon equally distant from the magnetic meridian, *and that the most elevated points of each arch are exactly in this meridian.* From these two facts, he concludes that there is a relation between the causes of the aurora borealis and the motions of the magnetic needle; and, from observations made in places remote from each other, he infers that the aurora acts even before it shows itself in the horizon, and that its influence is exerted at very considerable distances. In a subsequent paper on the subject, M. Arago showed that the auroræ which are visible only in America, at St Petersburg, and in Siberia, in spite of the immense distance which separates us from these regions, produces a perceptible derangement of the magnetic needle at Paris. M. Arago at first believed that even the auroræ of the southern hemisphere extended their influence to Paris; but he afterwards found, that on the days when these southern auroræ took place, the phenomenon was observed also in the N., so that no conclusion can be properly deduced from this coincidence with the observed derangements of the needle.

Kupffer.

M. Kupffer confirmed by his own observations the first results obtained by M. Arago, and concluded that the aurora extends its influence to a great distance. When the needle was driven from its mean position by the influence of this meteor, M. Kupffer could not perceive any sensible difference between the duration of an oscillation at this time and at any other. He has, however, excepted some cases where the deviation was very considerable; but what was very remarkable was, that when the needle deviated to the E., the duration of an oscillation was greater than usual, whilst on the 24th November 1825, when the needle deviated to the W., the duration of an oscillation was smaller. On the other hand, the dip being in the ratio of the duration of the oscillation, the preceding observations seem to prove that the dip diminishes when the needle deviates to the W., and increases with an easterly deviation.

Notwithstanding the body of evidence which proves the connection between the aurora and the derangement of the needle, it is a very remarkable fact, that during the frequent occurrence of that meteor at Port Bowen, Captain Foster did not observe any peculiar changes in the deviation of the needle, although, from his vicinity to the magnetic pole, the diurnal variation sometimes amounted to 4° or 5°, and it was to be presumed that the slightest action of the aurora would, under such circumstances, have been visible. From these observations of Captain Foster and others, the natural conclusion is, that there are some auroræ which do not disturb, while there are others which do disturb, the magnetic needle.

During Captain (now Sir George) Back's residence at Fort Reliance (N. Lat. 62. 46. 29., and W. Long. 109. 0. 39.) for *six* months in 1833–4, and *four* months in 1834–5, the aurora occurred almost every night. The magnetic needle seems to have been constantly affected by it, and on one occasion the effect exceeded *eight degrees.* "Brilliant and active coruscations of the aurora borealis," says Sir G. Back, "when seen through a hazy atmosphere, and exhibiting the prismatic colours, almost invariably affected the needle. On the contrary, a very bright aurora, though attended by motion, and even tinged with a dullish red and a yellow, in a clear blue sky, seldom produced any sensible change, beyond, at the most, a tremulous motion.

"A dense haze or fog, in conjunction with an active aurora, seemed uniformly favourable to the disturbance of the needle; and a low temperature was favourable to brilliant and active coruscations. On no occasion, during two winters, was any sound heard to accompany the motions. The aurora was frequently seen at twilight, and as often to the eastward as to the westward. Clouds, also, were often perceived in the day time, in form and disposition very much resembling the aurora."

Christie.

Mr Christie explained the absence of any apparent action of the aurora, by the supposition that the apparatus employed was not fitted to exhibit that action; and he entertained therefore the opinion, "that changes in the deviation and intensity of the terrestrial forces are simultaneous with the aurora borealis." The following is the method

Christie.

recommended by Mr Christie for observing the effects of the aurora to the greatest advantage :—

"If the magnetic forces brought into action during an aurora are in the direction of the magnetic meridian, they will affect a dipping needle adjusted to the plane of that meridian ; but the direction of a horizontal needle will remain unchanged. On the other hand, if the resultant of these forces makes an angle with the meridian, the direction of the horizontal needle will be changed, but the dipping needle may not be affected. In order to determine correctly the negative influence of the aurora, by means of a horizontal needle, it is therefore necessary not only to have regard to those forces which influence its direction, but likewise to those which affect the horizontal intensity. . The effects of the former are the objects of direct observation, but those of the latter are not so immediately observable. As, during an aurora, the intensity may vary at every instant, and it is these changes which are to be detected, the method of determining the intensity by the time of vibration of the needle cannot here be applied, and other means must be adopted. The best method appears to me to be that which I employed for determining the diurnal variation of the horizontal intensity, the needle being retained nearly at right angles to the meridian by the repulsive force of a magnet, or by the torsion of a fine wire or thread of glass. For the purpose, then, *of detecting, in all cases, the magnetic influence of the aurora*, I consider that two horizontal needles should be employed ; one adjusted in the meridian, for determining the changes which may take place in the direction of the horizontal force, and the other at right angles to the meridian, to determine the changes in the intensity of that force, arising principally from new forces in the plane of the meridian, and which would affect the direction of the dipping needle alone. Both these needles should be delicately suspended, either by very fine wire, or by entwisted fibres of silk. In order to render the changes in the direction of the needle in the meridian more sensible, its directive force should be diminished by means of two magnets N. and S. of it, and having their axes in the meridian. These magnets should be made to approach the needle until it points about 30° on either side of the meridian, and they should be so adjusted that the forces acting upon the needle will retain it *in equilibrio*, with its marked end at about 30° to the E. and 30° to the W. of N., and also at S. The needle is to be left with its marked end pointing S., for the purpose of observing the changes occurring in its direction. If magnets are employed to retain the second needle nearly at right angles to the meridian, they should be made to approach its centre until the points of equilibrium are at about 80° E., 80° W. and S., the observations being made with the needle at 80° E. and 80° W. An objection to this method of adjusting this needle by means of magnets is, that any change in their temperature will have a very sensible effect on the direction of the needle in this position ; and should such change take place during the observations, corrections must be applied to the results before any accurate conclusions can be drawn from them. I have before remarked, that this inconvenience will be in a great measure obviated by employing the torsion of a fine wire, or a very fine plummet of glass, to retain the needle at about 80° from the meridian. In this case, the ratio of the force of torsion to the terrestrial force acting upon the needle having been determined, a measure will be obtained of the changes which take place in the intensity of the terrestrial force during the occurrence of an aurora. It is very desirable that it should be ascertained whether the effects on the needle are simultaneous with any particular class of phenomena connected with the aurora ; whether these effects are dependent on the production of beams or coruscations, or on the formation of luminous arches ; or whether any difference exists in the effects produced by them. In order to determine this, it is necessary that the times of the occurrence of the different phenomena, and also of the changes in the directions of the needles, should be accurately noted ; and for such observations three observers appear to be indispensable."

Influence of electricity on the needle.

Mr Christie.

Sir Everard Home.

It has been considered a question of some importance, whether the electric state of the clouds produces any effects upon the needle : and this question has increased in interest since the discovery of the magnetical effects of galvanic and common electricity. Mr Christie made some valuable observations on this subject. Adjusting in a particular manner a needle between two magnets, so that its directive force was considerably diminished, he found that changes in the position of electric clouds were accompanied by changes in the position of the needle. Captain Sir Everard Home also observed, that, in two instances, a vibrating needle came sooner to rest during a thunder-storm than it did either before or after it. The number of vibrations was reduced in one case from 100 to 40, and in another from 200 to 120.

Sir George Back.

An analogous fact was observed by Sir George Back, in 1833, at Fort Alexander, at the southern extremity of Lake Winnipeg, where a "considerable alteration appeared, both in the number of vibrations, and the point at which the needle finally rested. A second time showed a similar discrepancy. The reason of this peculiarity I could not divine, until about an hour afterwards, when some gentlemen arrived from the westward, and acquainted us that they had just encountered a severe thunder-shower, though the sky over the fort underwent no visible change, and wore the same sultry aspect as it had done most of the forenoon."[1]

The view which we have given, in a subsequent section, of the magnetic condition of our atmosphere, arising from the uniform dissemination of ferruginous and other metallic matter, enables us to give a satisfactory explanation of the general phenomena of the aurora, of its action on the needle, and of the circumstances under which it will affect or not affect its stability. That there is magnetic matter in the atmosphere is indubitable, and that this matter may be heated by the electricity of the atmosphere, so as to give out light of different colours, and may have its magnetic influence increased or diminished by this electrical action, as well as by ordinary changes of temperature, cannot be doubted. When the magnetic forces are in a state of equilibrium, the needle will take its mean position, subject only to those diurnal changes which arise from the action of solar heat. But when the magnetic matter is exposed to the electrical agents which exercise so powerful an influence on the regions of the clouds, when the ferruginous matter, and the other metallic vapours which accompany it, are rendered luminous by the transmission of the electric fluid, and when the magnetic matter has its induced magnetism either diminished or increased by this cause, the resultant of the forces which act upon the needle must be changed, and motions regular and irregular, easterly and westerly, or in any given direction, communicated to a needle freely suspended by its centre of gravity. A local displacement of the magnetic matter, by the various causes which are constantly disturbing our atmosphere, or local and limited electric action, must necessarily affect such a needle ; but it is easy to conceive that those local and limited actions may be such as to balance each other, and not change the direction of the resultant force which acts either upon a horizontal or a dipping needle. Nay, it is easy to conceive a general diffusion of electricity, capable of illuminating the magnetic matter with such perfect equality in all magnetic azimuths, without at all affecting any needle, however balanced or suspended; because the electrical influence may not change the direction of the resulting forces which give the needle its mean direction. In such a case, however, it is probable that the magnetic intensity might be increased or diminished during the existence of such an electric state of the magnetic matter. We cannot, therefore, adopt the opinion of Mr Christie, *that every aurora must disturb the magnetic needle;* and we admit only the observed fact, that there are auroræ which disturb, and auroræ which do not disturb the needle.

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[1] *Narrative of the Arctic Land Expedition*, &c., p. 41, 42.

In order to explain more fully our views on this subject, let us suppose our magnetic atmosphere to be undisturbed by any cause, and that the needle in every magnetic meridian rests in a state of perfect equilibrium in its mean position. Let us now suppose that the magnetic atmosphere is disturbed in east longitude 90° and latitude 0°, either by a change of temperature, or by electric action, or by any cause which displaces the magnetic matter from that meridian, or accumulates it there. Such a change must necessarily affect the horizontal magnetic needle in all places to the east and west of it; but it will not affect the horizontal needle in the meridian where it takes place, or in the opposite meridian, as the resultant of the magnetic forces, though they may be changed in intensity, will not be changed in direction. In like manner, if various discharges take place simultaneously or successively, there will be certain places where the direction of the resultant forces is not changed, and other places where the change of direction is a maximum. A universally suspended needle, however, will have its direction always changed, unless when the disturbing cause is in the direction of its axis, or in a plane perpendicular to that axis. Hence, then, it is easy to understand (nay, the fact is a necessary result of our hypothesis) why there are auroræ which disturb and auroræ which do not disturb the needle, why distant auroræ affect it when nearer ones do not, and why the needle is in a shivering or constantly oscillating state during auroræ in which the places where the magnetic atmosphere is disturbed are constantly changing. In the same manner, we may account for the influence on the needle, observed by Sir Everard Home and Sir George Back, during the prevalence of a thunder storm, while the electricity of the atmosphere destroys by its action the magnetic equilibrium, when this action is not compensated by an equal one on the opposite side of the magnetic meridian. When such a compensation takes place, the needle will not deviate from its mean position, though the number of its vibrations in a given time may be altered.

Among the other causes which have a tendency to disturb the magnetic needle, we may enumerate earthquakes and volcanic eruptions, all of which are accompanied in general with electrical phenomena. In 1767 Daniel Bernoulli observed the dip of the needle to diminish half a degree during an earthquake; and De la Torre observed changes of several degrees in the variation of the needle during an eruption of Vesuvius.

In treating of the periodical disturbances, or irregular changes, in the variation of the needle, Dr Lloyd arrives at the conclusion that there are probably *two classes* of disturbances, the results of distinct physical causes, one of which is periodical, and the other wholly irregular; the former being *local* (depending on the time at the place of observation) and the latter *universal.* The principal, if not the only one, of the periodical disturbances, occurs a few minutes before ten P.M., and causes the north pole of the magnet to deviate to the east. Its mean magnitude is 10′·0 and its mean duration an hour and a half.

SECT. II.—*On the Dip or Inclination of the Needle.*

Dip of the needle.

The dip or inclination of the needle is, as we have already had occasion to observe, the angle which a well-balanced needle forms with the horizon after it is rendered magnetic, and when it has the power of free motion in the plane of the magnetic meridian, as shown in fig. 59, where NS is the needle balanced on a horizontal axis, at right angles to its length.

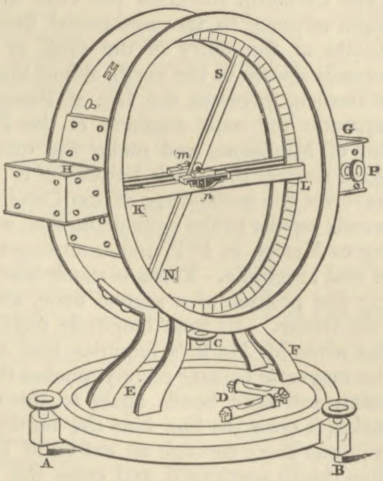

Fig. 59.

The dip of the needle, like the variation, has different values in different parts of the globe; generally speaking, being nothing, or horizontal, near the equator, and 90°, or perpendicular to the horizon, at the magnetic poles. The line passing round the globe near its equator, in every part of which the dip is nothing, is called the *magnetic equator*, which is a very irregular line, crossing the equator at *four* points, as shown in the annexed figure, where the black line E E is the real equator, and the dotted line MMM the magnetic equator, which is seen to cross the other at four points, in place of two.

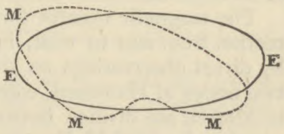

Fig. 60.

The general inclination of the magnetic to the terrestrial equator is about 12°, its principal intersections or nodes being placed in 113° 14′ west longitude and 66° 46′ east longitude from Greenwich; and it is a tolerably regular line throughout one-half of its circumference in the Atlantic and Indian Oceans. In discussing the observations made by Cook and others in the South Sea, M. Biot has shown that the above elements are incorrect everywhere beyond the western node, between 115° and 270° west longitude; and he concludes that between 256° and 158° 50′ of west longitude it again cuts the terrestrial equator at least once, which renders it necessary that it cut it another time near the east coast of Asia, provided it is found in the Atlantic Ocean or the south latitude. Hence there will be at least three nodes, and perhaps four, as shown in the preceding figure. This singular inflexion of the magnetic equator in the South Sea has been confirmed by the more recent observations of M. Freycinet.

Morlet and Hansteen.

The exact position of these nodes, and the true form of the magnetic equator, were determined with great care by MM. Morlet and Hansteen. There are some slight differences between their results, which have been pointed out by Arago, in the following excellent summary of the results of their inquiry:—Both Morlet and Hansteen place the magnetic equator wholly to the south of the terrestrial equator, between Africa and America; its greatest southern latitude being at 25°, one node is in Africa, in about 22° of east longitude, or in 18° according to Morlet. In setting out towards the east from this node, which is nearly in the centre of that part of the African continent, the magnetic equator advances rapidly to the north of the terrestrial equator, quits Africa a little to the south of Cape Guardafui, and in the Arabian Sea it attains its most northerly latitude of about 12°, in 62° of east lon-

Morlet and Hansteen.

gitude. Between this meridian and 174° east, the magnetic equator is constantly to the north of the equinoctial line. It cuts the Indian Peninsula a little to the north of Cape Comorin, traverses the Gulf of Bengal, making a slight advance to the equinoctial, from which it is only 8° distant at the entry of the Gulf of Siam. It then reascends a little to the north, almost touches the north point of Borneo, traverses the Isle of Paragua, the strait which separates the most southern of the Philippines from the Isle of Mindanao, and under the meridian of Naigiou it again reaches the north latitude of 9°. From this point it traverses the archipelago of the Caroline Islands, and descends rapidly to the equinoctial line, which it cuts, according to Morlet, in 174°, and according to Hansteen in 187°, of east longitude. There is much less uncertainty respecting the position of a second node, also situate in the Pacific Ocean. Its west longitude ought to be about 120°; but while M. Morlet's inquiries lead him to conclude that the magnetic equator merely touches the equinoctial at that point, and then bends again to the south, M. Hansteen makes it cross the line into the northern hemisphere, and continue there through an extent of 15° of longitude, and then return southward, and cross the equinoctial again in about 108° of west longitude, or 23° from the west coast of America. This discrepancy between the deductions of Morlet and Hansteen is, after all, very trivial; for, in the case just mentioned, the magnetic equator does not go more than 1½° to the north of the equinoctial; and, in general, the magnetic equator of Morlet differs in no part so much as 2° in latitude from that of Hansteen.

The magnetic equator thus traced over the globe has a motion from east to west, in so far as can be determined by direct observations on the position of its nodes. The two nodes of Hansteen, corresponding to the tangent node of Morlet, are divided between 108° and 126° of west longitude. In 1819 M. Freycinet found, on board the Uranie, that this node was in 132° of longitude; and General Sabine found that the node in Africa, which was far from the coast in 1780, had advanced from east to west even to the Atlantic Ocean. M. Morlet had indicated, with some distrust, this motion of the magnetic equator; and he considered it probable that its form and position regulated the direction of the annual variations of the needle. He found that the dip of the needle diminished wherever the motion of the equator tended to diminish the magnetic latitude, and that it increased, on the contrary, wherever the magnetic latitude was increased; a result which was confirmed by future observations.

Admiral Duperrey.

Much light has been thrown on the subject of terrestrial magnetism, but particularly on the form and motion of the magnetic equator, by the observations of Admiral Duperrey, made on board the Coquille, in the years 1822–1825. This vessel crossed the magnetic equator six times, and Duperrey was able to determine directly two of its points, situate in the Atlantic Ocean. On the chart of M. Morlet, and in that of Hansteen, the latitudes of those parts which correspond to the same longitudes are greater by 1° 43′ and and 1° 50′; and hence Arago concluded that the magnetic equator has approached the terrestrial equator by the same quantities. In the South Sea, near the coast of America, Duperrey determined two points of the magnetic equator. On the charts of Morlet and Hansteen the latitudes of these points is about a degree smaller, but the difference is in a direction contrary to that which was found in the Atlantic Ocean; from which it follows, that near the coast of Peru the magnetic equator has removed from the equinoctial line.

In discussing the magnetic observations made on board the Coquille, Duperrey has traced the form of the magnetic equator with an unexpected degree of accuracy; employing the formula of Barlow, which makes the tangent of the magnetic latitude equal to half the tangent of the dip, and making one only of dips which do not exceed 30°. Having obtained the magnetic latitudes of the places where the observations were made, he deduces, both from these and from the variation of the needle at the same place, the changes in longitude and latitude, which, being combined with the geographical positions of the stations, give him the co-ordinates of the corresponding points of the magnetic equator. By means of this method, and relying only on his own observations, he has traced a portion of this curve through an extent of 247° of longitude, comprehending the Atlantic Ocean, a part of South America, the great equinoctial ocean, and the Asiatic archipelago, as far as the western extremity of the island of Borneo. In prolonging the magnetic equator to the east, he has used the observations of General Sabine in 1822, made in the island of St Thomas, in the Gulf of Guinea. Between the west of Borneo and the north of Ceylon, he availed himself of the observations made in 1827 by M. de Blosseville, in the Chevrette. Adopting General Sabine's determination of one of the nodes of the magnetic equator, which he places 3° 20′ to the east of the meridian of Paris, not far from the west coast of Africa, Duperrey shows that this equator, after resting at this node, rises to the north, traverses Africa, and reaches probably 15° of north latitude, in the Red Sea (as appears from an observation made by Pantin in the Isle of Socotra in 1776). It then descends a little to the south, to join a point in it fixed by M. Blosseville in the north of Ceylon. From these facts it appears, *that the magnetic equator will meet the equinoctial line only in two points, which are diametrically opposite, the one situate in the Atlantic Ocean, and the other in the great ocean nearly in the plane of the meridian of Paris. When this equator meets only some scattered islands, it recedes only a little from the equinoctial line. When the islands are more numerous, it recedes farther; and it reaches its maximum deviation in both hemispheres only in the two great continents which it traverses. He found also, that between the northern and southern halves of the magnetic equator, there is a symmetry very remarkable, and much more perfect than had been previously believed.* These results are laid down by Duperrey in a chart of the equatorial regions published in the *Ann. de Chimie* for 1830.

The dip of the needle increases on each side of the magnetic equator, and Hansteen has projected the lines of equal dip in his chart already referred to. These lines are nearly parallel to the magnetic equator, till we reach 60° of north latitude, and they then begin to bend round the American magnetic pole, which Commander Ross found to be situate in north latitude 70° 5′ 17″, and west longitude 96° 45′ 48″, the needle having at this point, in Boothia Felix, lost wholly its directive power, and the dip being 89° 59′, within a minute of 90°. Had we inferred the position of the needle from the form of the magnetic equator, we should have placed it in 25° of west longitude, viz., the meridian in which the magnetic equator advances farthest to the south, or about 13½°, and in 76½° of north latitude, or 90° – 13½°. This, however, as all the arctic observations prove, is not the case; and we are led by the phenomena of the dip, as well as by those of the variation in different points of the globe, to conclude that every place has its own magnetic axis, with its own pole and its own equator, as already stated by Mr Barlow.

The following table contains the best observations on the dip of the needle, as collected by Professor Hansteen, and also the magnetic intensities from the equator to the poles:—

Places of Observation.	Dip.	Intensity.	Places of Observation.	Dip.	Intensity.	Places of Observation.	Dip.	Intensity.
	South.			North.			North.	
Port du Nord	75° 50′	1·5773	Mailand	65° 40′	1·3121	Korset	72° 24′	1·3735
Port du Sud	70 48	1·6133	Montpellier	65 53	1·3482	Quistrum	72 27	1·4070
Surrobaya in Java	25 40	0·9348	Airola	65 55	1·3090	Skieberg	72 29	1·3725
Amboyna	20 37	0·9532	Turin	66 3	1·3364	Elleoen	72 38	1·3340
Lima	9 59	1·0773	Medina del Campo	66 9	1·2938	Helgerone	72 39	1·3980
Magnetic Equator in Peru	0 0	1·0000	Lans le Bourg Mont Cenis	66 9	1·3227	Soner	72 41	1·3835
	North.		Como	66 12	1·3104	Christiania	72 34	1·4195
Tompenda	3 11	1·0191	St Michel	66 12	1·3488	Ryenberg	72 45	1·4208
Loxa	5 24	1·0095	Lyons	66 14	1·3334	Bogstad	72 34	1·4378
Cuença	8 43	1·0286	St Gothard	66 22	1·3138	Bogstadberg	73 13	1·4195
Quito	13 22	1·0675	Mont Cenis	66 22	1·3441	Nasoden	73 2	1·4517
St Antonio	14 25	1·0871	Ursern	66 42	1·3069	Bärum	72 44	1·3902
St Carlos	20 47	1·0480	Altorf	66 53	1·3228	Bolkesjoe	73 15	1·4053
Popayan	20 53	1·1170	Atlantic Ocean			Ingolfsland	73 19	1·4159
Santa Fe de Bogota	24 16	1·1473	37° 14′ n. 3° 30′	67 30	1·3155	Norsteboe	73 33	1·4136
Javita	24 19	1·0675	38 52 – 3 40	67 40	1·3155	Drammen	73 37	1·3771
Esmeralda	25 58	1·0577	Madrid	67 41	1·3938	Maursäter	73 44	1·4656
Carichana	30 24	1·1575	Tübingen	68 4	1·3569	Ullensvang	73 44	1·4260
St Thomas	35 6	1·1070	Atlantic Ocean			Gran	73 45	1·4221
Carthagena	35 15	1·2938	38° 52′ n. 3° 40′	68 11	1·3155	Köngsberg	73 47	1·4144
Cumana	39 47	1·1779	Ferrol	68 32	1·2617	Tomlevold	73 50	1·4246
Mexico	42 10	1·3155	Paris	69 12	1·3482	Bekkervig	73 58	1·4114
Atlantic Ocean			Göttingen	69 29	1·3485	Vang	73 59	1·4308
B. 20° 46′ n. L. 41° 26′ w. F.	41 46	1·1779	Berlin	69 53	1·3703	Bergen	74 3	1·4220
— 11 0 – — 44 32 —	41 57	1·2617	Carolath	68 21	1·3509	Moe	74 3	1·4254
— 12 34 – — 33 14 —	45 8	1·2300	Berlin	68 50	1·3533	Mauristuen	74 4	1·4058
— 14 20 – — 28 3 —	52 55	1·2830	Dantzig	69 44	1·3737	Leierdal	74 6	1·4190
— 20 8 – — 8 34 —	56 42	1·2510	London	69 57	1·3697	Slidre	74 34	1·4543
— 21 36 – — 5 39 —	47 49	1·2617	Ystad	70 13	1·3742	Brassa	74 21	1·4471
— 25 15 – — 0 36 —	60 18	1·2830	Schleswig	70 36	1·3814	Davis Straits,		
Portici	60 5	1·2883	Copenhagen	70 36	1·3672	68° 22′ n. 36° 10′ w.	83 8½	1·6365
Naples	61 35	1·2745	Odensee	70 50	1·3650	Hare Island,		
Rome	61 57	1·2642	Helsinburg	70 52	1·3782	70° 26′ n. 37° 12′ w.	82 49	1·6406
Vesuv. Crater	62 0	1·1933	Kolding	70 53	1·3846	Baffin's Bay,		
St Cruz, Teneriffe	62 25	1·2723	Soroe	70 57	1·3842	75° 5′ n. 42° 43′ w.	84 25	1·6169
Valencia	63 38	1·2405	Freidrichsburg	70 59	1·4028	75 51 – 45 26 —	84 44½	1·6410
Florence	63 51	1·2782	Aarhuus	71 13	1·3838	76 45 – 58 20 —	86 9	1·7052
Atlantic Ocean			Aalborg	71 27	1·3660	76 0 – 60 41 —	86 0	1·6885
32° 16′ n. 2° 52′ w.	64 21	1·2938	Odensala	71 39	1·3666	70 35 – 49 15 —	84 39	1·6837
Barcelona	64 37	1·3482	Friedrichshaven	71 48	1·3842	Magnetic Pole,		
Marseilles	65 10	1·2938	Göttenburg	71 58	1·3826	70° 5′ 17″ n. 96° 45′ 48″ w.	89 59	
Nîmes	65 23	1·2938	Altorp	72 14	1·3891			

On the Progressive Change in the Dip of the Needle.

Progressive change in the dip.

The dip of the needle, like the variation, undergoes a continual change, increasing in some parts of the world, and diminishing in others. The following table shows the change which has taken place in the dip at Paris from 1671 down to 1829:—

Year.	Dip.	Year.	Dip.
1671	75° 0′	1818	68° 35′
1754	72 15	1819	68 25
1776	72 25	1820	68 20
1780	71 48	1821	68 14
1791	70 52	1822	68 11
1798	69 51	1823	68 8
1806	69 12	1824	68 7
1810	68 50	1825	68 0
1814	68 36	1826	68 0
1816	68 40	1829	67 41 Arago.
1817	68 38		

The following table shows the changes of the dip at London from 1720 to 1833:—

Year.	Observed.		Computed
1720	74° 42′	Graham.	76° 27′
1773	72 19	Heberden.	73 40
1780	72 8	Gilpin.	73 18
1790	71 53	Ditto.	72 39
1800	70 35	Ditto.	71 58
1810	...	...	71 15
1818	70 34	Kater	70 34
1821	70 3	Sabine.	...
1828	69 47	Ditto.	69 43
1830	69 38	Kater.	...
1833	...	...	69 21

The last column in the table was calculated by Professor Barlow, by his formula, $2\ \text{cotan}\ \pi L = \text{tan. dip}$, or that the tangent of the dip is equal to double the tangent of the magnetic latitude.

The progressive variation in the dip of the needle is, as Humboldt has shown, the necessary consequence of a change in the magnetic latitude, arising from the motion of the nodes of the magnetic equator modified by the form of this curve; and M. Morlet applied the same principle to account for the variations of the dip in different parts of the globe.

Humboldt and Arago have endeavoured to deduce the annual diminution of the dip occasioned by the motion of the magnetic equator. By comparing the observations of 1778 and 1810 for Paris, the annual diminution was about 5′, whereas, from those of 1820 and 1825, it appears to be only 3′·3. The observations at Turin from 1805 to 1826 give 3′·5, and those of Florence 3′·3.

Besides the progressive variation of the dip, Hansteen has found, from a series of observations made with a dipping needle by Dollond, that the dip during the summer was about 15 minutes greater than during the winter, and about 4 or 5 minutes greater in the forenoon than in the afternoon.

SECT. III.—*On the Intensity of Terrestrial Magnetism.*

Intensity of terrestrial magnetism.

The determination of the intensity of the earth's magnetism at different points of its surface, and of the changes which it undergoes either progressively, or at different times of the day, and different seasons of the year, has become one of the most important practical problems connected with the physical condition of the globe.

The method of determining this important element by the number of oscillations of the needle was first suggested by Graham, and brought to perfection by Coulomb, Humboldt, and Hansteen. Observations on the dip and magnetic intensity were made between 1791 and 1794 at Brest, Teneriffe, Van Diemen's Land, Amboyna, and Surabaya. They were published in the second volume of the *Voyage d'Entrecarteaux* in search of Laperouse. If a needle whose axis of suspension passes through its centre of gravity, and which has its north polar and south polar magnetism equal, and similarly distributed, is made to vibrate by turning it from its position, and allowing it to receive that position by a series of oscillations, it is obvious that the earth's magnetism acts with equal force on each half, and that both these forces tend to draw the needle into the magnetic meridian. The greater the magnetic force, the more quickly will the needle oscillate and recover its primitive position. The needle is, in short, in the same circumstances as a pendulum oscillating by the action of gravity; and, as in this case, the forces are as the squares of the number of oscillations made in the same time.

Let us now suppose, to take the simplest case, that we make the dipping needle oscillate in the plane of the magnetic meridian, round the line of the dip, and that when the experiment is performed at the equator, the number in a second is 24, while in another place it is 25; then the intensities of the magnetic force at these places is as 25^2 to 24^2, or as 625 to 576, or as 1·085 to 1·000. By carrying the same needle to different parts of the earth, the magnetic intensity at these places will be found from the number of its oscillations.

In the application of this method there are various practical difficulties, particularly the necessity of its resting upon knobs, edges of steel, or agate, during its oscillation, which do not exist if we make a needle oscillate horizontally when suspended by a fine fibre of silk. This latter method has, therefore, been the one universally employed, though a little calculation is necessary to obtain the intensity of terrestrial magnetism from the number of oscillations which are performed.

Let NS be a magnetic needle suspended horizontally by a fibre of silk P, and let NC be the line of the dip, or ANC=D the dip itself. Then if F is the force of terrestrial magnetism acting upon the oscillating needle, and tending to bring it to rest, we may decompose this force into two, viz., one, NB, acting in a vertical direction, and which, being counteracted by the suspended force, has no tendency to affect the needle; and the other, NA, acting horizontally, and tending to direct the needle, and cause it to oscillate. This force NA is the cosine of ANC, the dip D. Hence the force NA will be equal to F × cos D. For any other place where the magnetic intensity is F′ and the dip D′, the effective force will be F′ × cos D′; and if we call N the number of oscillations made in a second at the first place, and N′ the number at the second, we shall have $F \times \cos D : F' \times \cos D' = N^2 : N'^2$, and the ratio of the magnetic intensities at the two places, or

$$\frac{F}{F'}=\frac{N^2 \cos D}{N'^2 \cos D'}.$$

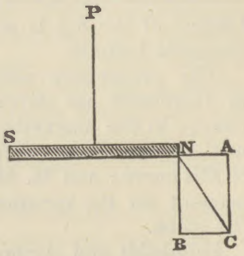

Fig. 61.

In this way observations on the magnetic intensity have been made in almost every part of the world, and a table containing upwards of 300 results, obtained principally by Professor Hansteen and his friends, was drawn up by himself, and republished in the last edition of this work. It contained the number of seconds in which 300 vibrations of the needle were performed, and the longitude and latitude of the places of observation. At that time these observations had not appeared in any English work, and had therefore a peculiar value; but we have not reprinted them, as a much more extensive and correct table of the actual magnetic intensities has been recently drawn up by General Sabine, and printed in the *Seventh Report of the British Association.*

The principal intensities computed from Hansteen's observations will be found in our table of the dip given above.

It appears from these data that the magnetic intensity increases from the equator to the poles, and the law of variation is shown in the following table:—

Dip of the Needle.	Magnetic Intensity.	Dip of the Needle.	Magnetic Intensity.
0°	1·0	73	1·4
24	1·1	76⅔	1·5
45	1·2	81	1·6
64	1·3	86	1·7

Professor Hansteen projected upon a map of the globe the lines passing through all the places in which the intensity has the same value. These lines he calls *isodynamic lines*, or those of *equal force*, and they are, generally speaking, nearly parallel to each other, and to the lines of equal dip.

Hansteen's observations in Siberia.

Many valuable observations on the intensity of the earth's magnetism were made during the numerous arctic expeditions which were sent out by the British government; but Professor Hansteen being extremely desirous of establishing, by direct observations of his own, the existence of the secondary magnetic pole, which he believed existed in Siberia, set out for this purpose in 1827, at the expense of the Norwegian Storthing, and with every encouragement and assistance from the Russian government. The results of this expedition exceeded his most sanguine expectations. The Russian Academy of Sciences were, in consequence of Professor Hansteen's scientific journey, induced to take a new interest in the subject of terrestrial magnetism, which exhibits such interesting features throughout the Russian empire; and the Russian government has since established regular observatories in different parts of its vast dominions, for making magnetical experiments. The Russian empire is actually traversed by *two* lines of no variation, and it is proposed to determine with great precision, every ten years, the exact position of these two lines. Near the first of them, which traverses European Russia, Petersburg, Moscow, and Kasan, are situate; and near the second, which passes through Siberia, are situate Kiachta and Nizni-Oudinsk.

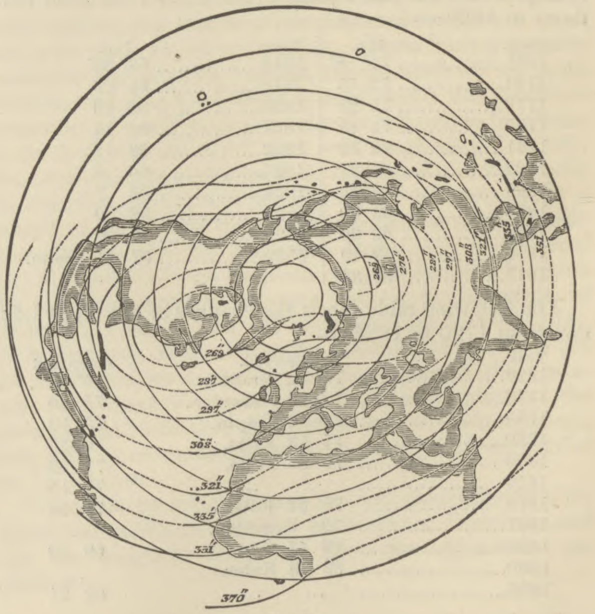

Fig. 62.

The principal observations made by Hansteen in Siberia have been laid down in a map of the northern hemisphere by General Sabine, along with other observations made by himself and Humboldt. In this map, of which the prefixed figure is a copy, it is exceedingly interesting to observe the isodynamic lines surrounding the two northern magnetic poles, and forming a series of returning curves similar to lemniscates, and which may be calculated by the formulæ of Sir David Brewster, already given in the History of Magnetism.

In this map the *American* pole is situated nearly in 60° of N. Lat. and 80° of W. Long.; and the *Asiatic* pole in 60° N. Lat. and 100° of E. Long. The black lines pass through the places where the magnetic intensity was observed to be equal, and the dotted parts of the same curves indicate the probable direction of the lines where observations had not been made. The lines round the American pole are laid down principally from General Sabine's observations, and those round the Asiatic pole from the later observations of Hansteen. The following is the account given by General Sabine of the different isodynamical lines in the figure:—

The *first* curve, or that nearest the magnetic poles, is that in which a magnetic needle which performs *n* oscillations in 300^s in London, performs the same number in 269^s round the Asiatic pole. This curve contains a smaller space than the corresponding curve round the American pole, which proves the inferior activity of the former pole. Hansteen traced the S. part of this curve below Lat. 60°, from the River Yenisei to 115° of W. Long.; that is, 25° beyond the Yenisei, and to Lat. 60°, where it takes a direction almost due north.

The *second* curve, or that in which the same number *n* oscillations are performed in 278^s, goes round both the American and Asiatic poles, including both within its area. It passes to the N.W. of Melville Island, and to the N.E. of some stations on the W. coast of Greenland; and it cuts the American coast between the Havannah and New York. Dr Erman, who accompanied Hansteen into Siberia, traced the same curve from the embouchure of the Oby, in N. Lat. 68°, and E. Long. 70°, following the direction of the River Mina as far as 60° N. Lat. The curve here gradually bends to the E., and after passing between Tobolsk and Narym, it was again detected by M. Hansteen at Kainsk, a few degrees to the S. of Lake Baikal.

The *third* curve, or that in which *n* oscillations are performed in 287^s, is drawn on the American side, from observations made at the Havannah, at the Pendulum Isle on the E. coast of Greenland, in N. Lat. 74° 5′ and between Spitzbergen and Hammerfest, near the North Cape. This curve, according to Hansteen, enters Europe between Archangel and Nova Zembla; and he met with it again between Moscow and Tobolsk, at 56½° of E. Long. and 57½° of N. Lat.

The *fourth* curve, or that in which *n* oscillations are performed in 297^s, passes near Jamaica, where the oscillations were performed in 294^s, and, after traversing the N. of Britain, it enters Norway to the S. of Bergen. Advancing eastward, it passes between Stockholm and Tornea, and thence by St Petersburg and Moscow.

The observations of Professor Hansteen do not extend farther S. than these lines, and therefore General Sabine has laid down in the map the line in which *n* oscillations are performed in 308^s, 321^s, 335^s, 351^s, and 370^s, from his own observations and those of Humboldt. The lowest number of seconds in which *n* oscillations are performed is at the magnetic poles, where it is nearly 262 or 263, and the greatest, 370, the time in which they are performed at the equator.

We have stated that the isodynamical lines are nearly parallel to those of equal dip. This is the case in Scotland; but towards the E., in Norway and Sweden, the lines of equal intensity bend more to the N., and cut the former; and also, under the same line of equal dip, the intensity is weaker to the E. than to the W. Hence Professor Hansteen found that the pole of the lines of equal dip lies in 71° of Lat., and 102° of Long., while the pole of intensity is in 56° of Lat., and 80 of Long. W. of Paris. The first of these determinations coincides very nearly with the pole of Sir James Ross, where the dip was 90°. The observations made during the arctic expeditions from England, and also those by Hansteen and Erman in Siberia, prove beyond a doubt the accuracy of the earlier conclusion of Hansteen, that the lines of equal intensity and equal dip are not parallel. Humboldt discovered the node of the magnetic equator with the isodynamical curve in 7° of S. Lat., and 81° of Long. W. of Paris. He traced this last line to the W. of the Cordilleras of the Andes, and along the coast of Peru, towards Kasma and Fluormay, even to the 10th degree of S. Lat. M. Adolphus Erman found in Siberia, that the isodynamic line, where the intensity is 1·60 (that of the equator being 1·00), directs itself also from N. to S. with a slight inclination to the S.E. He observed this line *cut almost at right angles the curves of equal dip*, and then descend from the N.N.W. to the S.S.E., from Ochotsk, near the mouths of the Oby, to Tomsk. Humboldt is of opinion that the isodynamical line and the Peruvian node of the magnetic equator have been carried, since his voyage, from E. to W.; and he informs us that M. A. Erman, in the 135th degree of Long. W. of Paris, and in the magnetic equator, found that the intensity of the magnetic forces was sensibly the same as he had found them twenty-six years before on the magnetic equator in Peru.

As the intensity of terrestrial magnetism at different places is not a function of the dip at these places, and the isodynamic lines are not parallel to those of equal dip, it is probable that different points of the equator have not the same magnetic intensity. "Having carried," says Humboldt, "the same needle or needles compared with them, from Paris to Mexico, to the magnetic equator in Peru, to Berlin, to Petersburg, to the shores of the Caspian, and to the N. of Asia, I have expressed the magnetic intensities at these places, by taking for unity the intensity which I find on the magnetic equator in Peru, or rather in the intersection of this equator with the isodynamical line of minimum intensity. On this supposition, I find for Paris 1·3482, for Milan 1·3121, for Naples 1·2745. The very valuable observations of M. Rossel, at Surabaya in Java, and those of General Sabine near St Thomas, 5° N. of the equator, indicate that the magnetic intensity is less on the magnetic equator near the W. coast of Africa (W. Long. 40° 24′), and in the great Italian archipelago, than in the portion of the magnetic equator which crosses Peru. Besides, M. A. Erman has observed, that on the E. coasts of South America the intensities are much weaker at the same distances from the S. terrestrial pole than on the W. coasts. The intensity 1·00, found to the W. of the new continent, on the magnetic equator in the South Sea, in 135° of W. Long., and 1° 55′ of S. Lat., shows itself on the coasts of Brazil towards the 38th degree of S. Lat., while the dip is there even more than 37° S. It appears to me more probable that the minimum intensity at the surface of the earth is to the maximum, not as 1 to 1·6 or 2, as has been supposed, but even much beyond the ratio of 1 to 2·6."

Observations are yet wanting to determine in what manner the intensity varies with the height. Humboldt is of opinion that it decreases, thus confirming the deductions of Kupffer.

By combining all the observations of intensity from 179° to 183°, Professor Hansteen came to the conclusion, *that the total magnetic intensity is smaller in the southern than in* *the northern hemisphere.* Admiral Duperrey confirmed this result. According to the investigations of Biot, the natural magnetic intensity, or I, is $= 2A \cdot \sqrt{\frac{1}{4 - 3\sin^2 \delta}}$, and that of the horizontal needle $= 2A\sqrt{\frac{1}{3 + \sec^2 \delta}}$, δ being the dip; but these formulæ presuppose that the earth is perfectly homogeneous, and of course they cannot be verified by insulated observations. Admiral Duperrey was therefore obliged, in order to bring all these observations into this state, to take the mean intensity of the terrestrial equator and of each of the parallels of the globe, and to multiply the circumference of each curve by its intensity in order to have the total intensity, and then to take the mean of the total intensities of the corresponding parallels in each hemisphere. In this manner he obtained all the points of the curve which represents the law of the increase of the magnetic forces from observation. The curve thus traced, when compared with that which is calculated by the formula of M. Biot, does not deviate from it above 0·015 of the intensity, supposing the intensity at the magnetic equator in Peru to be 1. He found also that the surface of the north magnetic hemisphere is to that of the south one in the ratio of 1·0000 to 1·0152, a ratio which is the same as that of the total intensity of the south terrestrial hemisphere to the total intensity of the north terrestrial hemisphere; and he hence concludes, that *the surfaces of the two magnetic hemispheres are proportional to the intensities of the two terrestrial hemispheres.*

The lines of equal magnetic intensity had the values 0·9, 1·0, 1·1, 1·2, &c., given to them in reference to an arbitrary unit, which was the measure of the force at the place in South America when Humboldt measured it early in the present century. Compared with this measure, the intensity in Paris was 1·348, and that in London 1·372. This arbitrary scale, however, though useful in bringing together the results obtained by different observers, assumed that the magnetic force was constant at the same place, whereas all the three magnetic elements are subject to change. Poisson first pointed out a method of surmounting this difficulty; but Gauss, in his work entitled *Intensitas vis Magneticæ*, already referred to, explained and introduced a method of determining the absolute magnetic intensity at the place where the experiment is made, expressed in terms of standards of weight and linear measure, and recognised subdivisions of time. As the absolute values of the intensity have the same relation to each other as the arbitrary values, it is necessary only to have the values of the two scales at one station to enable us to convert the one into the other at all other places.

The first general map of the isodynamic lines was laid before the British Association in 1837 by General Sabine; but he afterwards adapted it to 1840, and in the revised state he has published it in his admirable article forming plate 23 in the new edition of Johnston's *Physical Atlas*, just published. The lines are numbered on the arbitrary scale, but the relative absolute values, which are as follows, are given on the map:—

Arbitrary scale.	Absolute scale.	Arbitrary scale.	Absolute scale.
0·9	6·81	1·6	12·11
1·0	7·57	1·7	12·87
1·1	8·32	1·8	13·62
1·2	9·08	1·85	14·00
1·3	9·84	1·9	14·37
1·4	10·60	2·0	15·14
1·5	11·35	2·05	15·52

The first of these numbers, viz., 0·9, corresponds with the equatorial intensity in the Atlantic; and the last of them, viz., 2·05, with the maximum observed intensity in S. Lat. 60., and E. Long. 170. to 150.

In order to discover the causes of terrestrial magnetism, the localities in which they operate, and the laws which regulate the periodical changes which have been observed, maps of the three magnetic elements must be constructed in every part of the globe. The determination of these elements for the British Islands was undertaken in 1834, at the suggestion of the British Association, by General Sabine, Dr Lloyd, Sir James Ross, Mr Phillips, and Mr W. Fox, who published the result of their observations in the Reports of that body for 1838.[1] General Sabine proposes, that as 20 years have now elapsed, the observations should be repeated; and we would suggest that they should be made at the bottom of mines and the top of mountains.

Dr Kreil has made similar observations in 1846–54 in the Austrian States, and Dr Lamont in and around Bavaria in 1849–53. The Messrs Schlagintweit are occupied in the same work in British India; and Dr Bache in the United States of America, Captain Elliot in the Indian Archipelago, and Mr Vogel in Northern and Central Africa, at the expense of the British government.

On the Monthly and Daily Change of Intensity.

Monthly and daily changes of intensity.

The magnetic intensity, like the other elements of terrestrial magnetism, suffers monthly and diurnal changes. By means of the vibrations of a needle delicately suspended, M. Hansteen found that the *minimum* of the daily change of intensity is between ten and eleven in the forenoon, and the *maximum* between four and seven in the afternoon in May, and about seven in June. The intensity is a maximum in December, and a minimum in June. The greatest monthly change in the intensity is a maximum in the months of December and June, about the time when the earth is in its perihelion and aphelion. It is a minimum near the equinoxes, or when the earth is at its mean distance from the sun. The greatest daily change is least in the winter and greatest in the summer; the greatest difference of the annual change of intensity is 0·0359. Professor Hansteen likewise found that the magnetic intensity is diminishing in Europe, and that the decrease is greater in the northern and eastern, than in the southern and western parts, an effect which he conceives to be produced by the motion of the Siberian pole towards the east. At Port Bowen, Sir Edward Parry observed an augmentation of the magnetic intensity to take place from the morning till the afternoon, and a diminution of it from the afternoon till the morning. The results of Hansteen were also confirmed by Mr Christie,[2] who showed that the terrestrial magnetic intensity is a minimum between ten and eleven o'clock in the morning, the time nearly when the sun is in the magnetic meridian; that it increases from this time until between nine and ten o'clock in the evening, after which it decreases, and continues decreasing during the morning, till it reaches its minimum between ten and eleven. These results were deduced from observations made in May, *within doors*, to determine the positions of the points of equilibrium at which a magnetic needle was retained at different hours during the day, by the joint action of two bar-magnets and of terrestrial magnetism, reduced to their true positions at the standard temperature (60°) of the magnets. As this change in the position of these points was produced by the change in the magnetic intensity, Mr Christie thus obtained accurate measures of the last of these elements by means of the following formula:—

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[1] This report was published separately, entitled *Report on the Magnetic, Isoclinal, and Isodynamic lines in the British Islands.* Lond. 1839.

[2] *Phil. Trans.*, 1825, p. 49-51.

Terrestrial Magnetism.

$$M - F\,(\cdot004690814 + \cdot000829329 \cos^2 \varphi) = 0;$$

in which M is the horizontal part of the terrestrial magnetic force, acting on the north arm of the needle in the line of the dip, F the force with which a pole of the needle is repelled from a pole of the same name of either magnet, or attracted towards that of a contrary name at unity of distance, and φ the angle which the axis of the needle makes with the meridian, or the azimuth of the point of equilibrium.

Mr Christie repeated his observations in *the open air* in June, and from these it appears that the minimum intensity happened nearly at the time the sun passed the magnetic meridian, and rather later than in May, which was also the case with the time of the sun's passage over the meridian. The intensity increased until about six o'clock in the afternoon, after which it appears to have decreased during the evening, and to have been decreasing from an early hour in the morning. Mr Christie has given the following interesting view of Hansteen's results and his own :—

Intensity deduced from Hansteen's Observations in 1820.			Intensity deduced from Mr Christie's Observations in 1823.		
Time.	May.	June.	Time.	May.	June.
8 *h.* 0 *m.* A.M.	1·00034	1·00010	7 *h.* 3 *m.*	1·00114	1·00061
10 30	1·00000	1·00000	10 30	1·00000	1·00000
4 0 P.M.	1·00299	1·00251	4 30	1·00175	1·00223
7 0	1·00294	1·00304	7 30	1·00220	1·00239
10 30	1·00191	1·00267	9 30	1·00231	1·00209

The principal difference between these results is, that in Mr Christie's observations the intensity seems to diminish more rapidly in the morning, and increase more slowly in the afternoon, than it does in those of Hansteen.

The following table shows the horizontal magnetic intensity at Göttingen, as determined by Professor Gauss, in different months of 1832, with great accuracy.

1832.	Horizontal Intensity.	1832.	Horizontal Intensity.
May 21	1·7820	July 25, 26	1·7845
... 24	1·7694	Sept. 9	1·7764
June 4	1·7713	... 18	1·7821
... 24–28	1·7625	... 27	1·7965
July 23, 24	1·7826	Oct. 15	1·7860

In order to obtain from these numbers the absolute magnetic intensity, to compare them with the results in Hansteen's table, they must be multiplied by the secant of 68° 22′ 22″, the dip at Göttingen on the 23d June 1832.

SECT. IV.—*On the Nature and Causes of the Earth's Magnetism.*

Nature and causes of the earth's magnetism.

The phenomena described in the preceding sections afford abundant evidence that the earth is in some way or other magnetic; but what is the nature of its magnetic condition, or from what cause it derives its origin, are points which it is not easy to determine. The earliest and the most natural supposition is that of Dr Gilbert, that the earth contains within itself a powerful magnet, lying in a position which nearly coincides with its axis of rotation. In this case, the pole of this magnet, which acts in our northern hemisphere, must have south-polar magnetism, as it attracts the north pole of the needle; while the pole in the southern hemisphere must have north-polar magnetism, as it attracts the south pole of the needle. That this hypothesis would, generally speaking, represent the ordinary phenomena of terrestrial magnetism, may be easily shown by placing a bar-magnet within a terrestrial globe, and observing the phenomena exhibited by a small needle suspended at its centre of gravity by a fine thread or fibre. As the magnet is placed out of the axis of rotation, the needle in the northern hemisphere will always point to the north end of the inclosed magnet, exhibiting all the phenomena of the variation of the needle, as usually observed.

Terrestrial Magnetism.

Causes of the earth's magnetism.

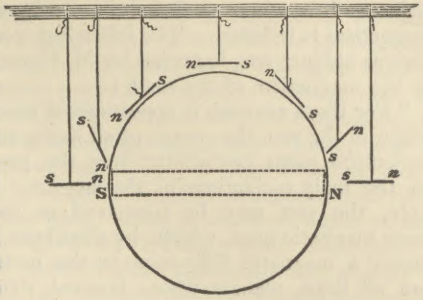

Fig. 63.

The general phenomena of the dip will also be exhibited, as shown in the annexed figure, where NS is the direction of the inclosed magnet, shown by dotted lines, S being the northern magnetic pole, and N the southern, and *ns*, *ns*, small needles suspended by fibres *f*, *f*, *f*. The needle has no dip at the equator, because each pole is equally attracted by the corresponding poles of the inclosed magnet, and at the poles S, N, the dip is 90°, as observed at the northern magnetic pole by Sir James Ross. At latitudes intermediate between the magnetic equator and the magnetic poles, the dip has an intermediate value.

In the same manner as a common bar-magnet communicates magnetism to a piece of soft iron held near it, the supposed magnet in the earth communicates magnetism to a soft iron bar held in the magnetic meridian, and parallel to the dipping needle, which in this country is not far from a vertical position. The soft iron is temporarily a magnet, exactly like the soft bar in the presence of a real magnet, and possesses the very same properties.

In the progress of discovery, however, it has been found that the phenomena of the dip and the variation are more complex than this hypothesis will allow us to suppose; and in measuring the magnetic intensity in Siberia, Hansteen has proved that there is another magnetic pole in that country, which regulates the magnetic phenomena. In order to account for these, we must therefore suppose another magnet passing through the globe in the direction of a diameter whose pole coincides with the Siberian magnetic pole. But even this addition to the hypothesis of Gilbert will not explain the phenomena, unless we resort to the absurd assumption of Halley, who gives rotatory movements to magnetic spheres placed in the interior of the globe.

A more sober and philosophical hypothesis is one which has been long gaining ground, and which later discoveries have rendered still more probable. According to this hypothesis, the magnetism of the earth is not that of a magnet, but that of a sphere or spherical shell of iron on which magnetism is induced. The difference between these two magnetic states is very great. In regular magnets the centres of action are placed at their extremities or poles; but in masses of iron, either hollow or solid, either regular or irregular, the centres of action are always coincident with the centre of attraction of the surface of the mass. When the observations on the variation and dip of the needle became numerous and accurate, philosophers soon perceived that they could not be explained by the action of two magnetic poles at a distance from each other. M. Biot had the merit of first viewing the subject in this light, and he at length came to the conclusion that the nearer the poles were taken to each other, the greater was the agreement between the computed and observed results; and by assuming the two centres as indefinitely near to each other in the centre of the earth, the coincidence between observation and calculation was as great as could be expected. Now, it is a remarkable fact, that Mr Barlow discovered, as we have already seen, that such a coincidence in the centre of action actually takes place in all bodies which are magnetic by induction, such as iron spheres or shells; and he has applied this principle to account for the various phenomena of the dip and variation of the needle. Almost all

Causes of the earth's magnetism.

Hansteen.

the philosophers who have since investigated the subject have adopted this idea; and the only difficulty which attaches to it is, where to find the cause by which the earth's magnetism is induced. The following speculations on this curious subject are hazarded by M. Hansteen, in his work on the magnetism of the earth: —

"For these reasons, it appears most natural to seek their origin in the sun, the source of all living activity; and our conjecture gains probability from the preceding remarks on the daily oscillations of the needle. Upon this principle, the sun may be conceived as possessing one or more magnetic axes, which, by distributing the force, occasion a magnetic difference in the earth, in the moon, and all those planets whose internal structure admits of such a difference. Yet, allowing all this, the main difficulty seems not to be overcome, but merely removed from the eyes to a greater distance; for the question may still be asked with equal justice, *whence did the sun acquire its magnetic force?* And if from the sun we have recourse to a central sun, and from that again to a general magnetic direction throughout the universe, having the milky-way for its equator, we but lengthen an unrestricted chain, every link of which hangs on the preceding link, no one of them on a point of support. All things considered, the following mode of representing the subject appears to me most plausible. If a single globe were left to move alone freely in the immensity of space, the opposite forces existing in its material structure would soon arrive at an equilibrium conformable to their nature, if they were not so at first, and all activity would soon come to an end. But if we imagine another globe to be introduced, a mutual relation will arise between the two; and one of its results will be a reciprocal tendency to unite, which is designated, and sometimes thought to be explained, by the merely descriptive word attraction. Now, would this tendency be the only consequence of that relation? Is it not more likely that the fundamental forces, being driven from their state of indifference or rest, would exhibit their energy in all possible directions, giving rise to all kinds of contrary action? The electric force is excited, not by friction alone, but also by contact, and probably also, though in smaller degrees, by the mutual action of two bodies at a distance; for contact is nothing but the smallest possible distance, and that, moreover, only for a few small particles. Is it not conceivable that magnetic force may likewise originate in a similar manner? When the natural philosopher and the mathematician pay regard to no other effect of the reciprocal relation between two bodies at a distance, except the tendency to unite, they proceed logically, if their investigations require nothing more than a moving power; but should it be maintained that no other energy *can* be developed between two such bodies, the assertion will need proof, and the proof will be hard to find.

"I reckon it possible, therefore, that, by means of the mutual relations subsisting between the sun and all the planets, as well as between the latter and their satellites, a magnetic action may be excited in every one of those globes whose material structure admits of it, in a direction depending on the position of the rotatory axes with regard to the plane of the orbit. Each of the planets might thus give rise to a particular magnetic axis in the sun; but as their orbits make only small angles with the sun's equator and each other, these magnetic axes would, perhaps, on the whole, correspond with the several rotatory axes. Such planets as have no moons would, on this principle, have but one magnetic axis; the rest would, in all cases, have one axis more than they have moons, if those different axes, by reason of the small angles which the orbits of their several moons form with each other, did not combine into a single axis. The conical motions by which the rotatory axes of the planets are carried round the pole of the ecliptic (the precession in the earth), joined to the revolving motion of the orbits about the sun's equator (which occasions the present diminution in the obliquity of the ecliptic), might perhaps, in this case, account for the change of position in the magnetic axis. It would greatly strengthen this hypothesis, if the above great magnetic period, after the lapse of which both axes again assume the same position, should in fact be found to coincide with the period of the precession, which, however, seems a little doubtful."

Such was the state of speculation on this part of the subject when Hansteen published his work on the magnetism of the earth. The poles of our globe were then regarded as the coldest parts on its surface; and no conjecture even had been hazarded regarding the connection between the phenomena of terrestrial temperature and terrestrial magnetism, till Sir David Brewster proved, from an immense number of meteorological observations, that there were in our northern hemisphere two poles of maximum cold; that these poles coincided with the magnetic poles; that the circle of maximum heat, like the magnetic equator, did not coincide with the equinoctial line; that the isothermal lines, and the lines of equal magnetic intensity, had the same general form surrounding and inclosing the magnetic poles and those of maximum cold; and that, by the same formula, *mutatis mutandis,* we could calculate the temperature and the magnetic intensity of any point of the globe. These views we have referred to more fully in the "History of Magnetism."

The monthly and daily changes in the intensity of terrestrial magnetism, and in the dip and variation of the needle, had led Canton and others to ascribe these changes to the action of the sun; and Admiral Duperrey, in his paper on the magnetic equator, demonstrated that the points of this great circle, or those where the magnetic intensity is minimum, are also the warmest points of each meridian, or that the thermal and the magnetic equator are connected, as we had already proved to be the case with the thermal and magnetic poles. Admiral Duperrey likewise attributes the differences in the magnetic intensities of different places to their difference of temperature; and he remarks, that in comparing the isothermal and the isodynamic lines, he found a remarkable analogy in their curvatures, and particularly in the direction of their concavities and convexities. In support of these views, Admiral Duperrey refers to the changes in the daily variation, as following the movements of the sun; and he infers that the southern hemisphere of our globe is a degree colder than the northern hemisphere.

But though it is now placed beyond a doubt, that the phenomena of temperature and magnetism are closely connected, and that the latter are powerfully influenced by the former, yet various questions arise, which it is very difficult to answer.

1. Have the phenomena of terrestrial magnetism an electric origin; that is, is the magnetism developed by electro-magnetic or thermo-magnetic causes? or,

2. Are the phenomena owing to the diffusion of iron or other magnetic metals through the solid mass of our globe, in which magnetism is induced by some exterior cause?

The electro-magnetic hypothesis, which was first stated by Sir David Brewster, was ably supported by Professor Barlow in a paper which appeared in the *Phil. Trans.* for 1831, *On the probable Electric Origin of all the Phenomena of Terrestrial Magnetism;* in which he considers it as probable, "that magnetism, as a distinct quality, has no existence in nature." As all the phenomena of terrestrial magnetism can be explained on the supposition that the magnetic power resides on its surface, it occurred to Mr Barlow, that if he could distribute over the surface of an artificial globe a series of galvanic currents, in such a way that their tangential power should everywhere give a corresponding direction to the needle, this globe would exhibit, while under electrical induction, all the magnetic phenomena of the earth upon a needle freely suspended above it. He accordingly put this idea to the test of experiment in the following manner:—

Barlow's electro-magnetic globe.

"I procured," says he, "a wooden globe sixteen inches in diameter, which was made hollow for the purpose of reducing its weight; and, while still in the lathe, grooves were cut to represent an equator, and parallels of latitude at every $4\frac{1}{2}°$ each way from the equator to the poles; these grooves were about an eighth of an inch deep and broad; and lastly, a groove of the same breadth, but of double the depth, was cut like a meridian, from pole to pole, half round. These grooves were for the purpose of laying in the wire, which was effected thus:—The middle of a copper wire nearly ninety feet long, and one-tenth of an inch in diameter, was applied to the equatorial groove, so as to meet in the transverse meridian; it was then made to pass round this parallel, returned again along the meridian to the next parallel; then passed round this again; and so on, till the wire was thus led in continuation from pole to pole.

"The length of wire still remaining at each pole was bound with varnished silk to prevent contact, and then returned from each pole along the meridian groove to the equator. At this point, each wire being fastened down with small staples, the wires of the remaining five feet were bound together to near their common extremity, where they opened to form two points for connecting the poles of a powerful galvanic battery.

"When this connection was made, the wire became of course an electric conductor, and the whole surface of the globe was put into a state of transient magnetic induction; and consequently, agreeable to the laws of action above described, a neutralized needle freely suspended above such a globe would arrange itself in a plane passing from pole to pole through the centre, and take different angles of inclination, according to its situation between the equator and either pole.

"In order to render the experiment more strongly representative of the actual state of the earth, the globe, in the state above described, was covered by the gores of a common globe, which were laid on so as to bring the poles of this wire arrangement into the situation of the earth's magnetic poles, according to the best observations we have for this determination. I therefore placed them in latitude 72° N. and 72° S., and on the meridian corresponding with longitude 76° W., by which means the magnetic and true equators cut one another in about 14° E., and 166° W. longitude.

"The globe being thus completed, a delicate needle must be suspended above it, neutralized from the effect of the earth's magnetism, according to the principle I employed in in my observations on the daily variation, and described in the *Philosophical Transactions* for 1823; by which means it will become entirely under the superficial galvanic arrangement just described. Conceive now the globe to be placed so as to bring London into the zenith, then the two ends of the conducting wire being connected with the poles of a powerful battery, it will be seen immediately that the needle, which was before indifferent to any direction, will have its north end depressed about 70°, as nearly as the eye can judge, which is the actual dip in London; it will also be directed towards the magnetic poles of the globe, thereby also showing a variation of about 24° to 25° to W., as is also the case in London. If now we turn the globe about on its support, so as to bring to the zenith places equally distant with England from the magnetic pole, we shall find the dip remains the same; but the variation will continually change, becoming first zero, and then gradually increasing to the eastward, as happens on the earth. If again we turn the globe so as to make the pole approach the zenith, the dip will increase, till at the pole itself the needle will become perfectly vertical. Making now this pole recede, the dip will decrease, till at the equator it vanishes, the needle becoming horizontal. Continuing the motion, and approaching the south pole, the south end of the needle will be found to dip, increasing continually from the equator to the pole, where it becomes again vertical, but reversed as regards its verticality at the north pole."

Barlow's electro-magnetic globe.

Although the artificial globe represents very exactly on a small scale all the phenomena of terrestrial magnetism, and although, as Mr Barlow says, "he has proved the existence of a force competent to produce all the phenomena, without the aid of any body usually called magnetic;" yet he acknowledges that, "we have no idea how such a system of currents can have existence on the earth, because, to produce them, we have been obliged to employ a particular arrangement of metals, acids, and conductors." The discovery of Dr Seebeck, however, that the mere application of heat to a circuit composed of two metals[1] is capable of developing the magnetic effects above described, is regarded by Professor Barlow as bringing us a step nearer to an explanation of the earth's magnetism, by referring us to nature as the great agent of all these phenomena, and he conceives that only one link is wanting to complete the explanation. This link, however, is a very important one, and we are just as much puzzled to discover the metallic thermo-magnetic apparatus, as we are to discover the electro-magnetic one. If it could be shown that the action of solar heat is capable of developing magnetism in particles such as those which are known to constitute our globe, the great difficulty would be removed; but until this is done, we are disposed to lean to the old though not yet exploded notion, that terrestrial magnetism is the effect of magnetic or ferruginous materials, which are disseminated through the mass of the earth. This leads us to consider the second question relative to the origin of terrestrial magnetism.

2. Are the phenomena owing to the diffusion of iron or other magnetic metals through the solid mass of our globe, on which magnetism is induced by some exterior cause?

In so far as our knowledge extends, iron and other magnetic metals are not so regularly diffused as to produce the magnetic phonomena; and we are not entitled to assume the existence of any regular metallic nucleus, or regular arrangement of metallic strata, capable of producing that uniform action in the magnetic needle which is indicated by the regularity of the isodynamical lines, or those of equal magnetic intensity. That there are actual magnets within the crust of our globe, and abundance of ferruginous matter capable of producing locally magnetic phenomena, cannot be doubted; but the action of these two classes of bodies is regulated by different laws, and we can only regard them as exercising a disturbing force in rendering irregular the action of some more general cause. If the ferruginous matter which produces magnetism is situated near the surface of the earth, we should expect a diminution in the intensity when the needle is made to oscillate above the deepest parts of the ocean, where the solid crust may be many miles distant. If it is, on the other hand, deeply seated, the intensity ought to diminish greatly as we ascend in balloons, or to the tops of our highest mountains; but none of these effects are observed, and it becomes therefore very improbable that the magnetic phenomena are produced either by ferruginous matter *near the surface, or far removed from it.*

But though we cannot find the seat, or rather the intermedium, of terrestrial magnetism in the bowels of the earth, may we not, as a last resource, seek for it *in our atmo-*

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[1] Mr Sturgeon of Woolwich produced similar effects by the application of heat to only one metal, viz., a rectangle of bismuth only.

Terrestrial magnetism supposed to reside in the atmosphere.

sphere? It appears to be demonstrated by the experiments of Fusinieri, of which we have given a full account in our article on ELECTRICITY, that metals, and *particularly iron*, exist in a state of vapour in our atmosphere; and hence we have a regular hollow shell of magnetic matter enveloping the earth, and capable, when magnetism is induced upon it by an exterior cause, of producing all the phenomena of terrestrial magnetism. In its undisturbed state of equilibrium, this magnetic atmosphere will act upon the needle, according to the laws which Mr Barlow found to regulate the action of an iron sphere or shell; but these laws will be modified by those which regulate the thermal state of the globe, and will be disturbed by sudden changes of temperature, and by the various electrical agencies which exercise so powerful an influence over the meteorological condition of the atmosphere. The more violent disturbances of electrical equilibrium will fuse, and throw down, in the form of meteoric stones, the metallic vapour in their vicinity. Inferior electrical actions will render their progress visible in the form of lightning and fiery meteors, arising from the heated state of the metallic particles; while still feebler electricities will, by their accompanying heat, produce the sheets of summer lightning, and the more continued and shifting phenomena of the aurora. Hence the electric sounds and other accompaniments of the aurora; hence its connection with the magnetic pole and equator; and hence the disturbance of the needle, or the *magnetic hurricanes*, as Humboldt calls them, while the regular action of the metallic atmosphere is disturbed during the prevalence of the aurora, or of thunder-storms. These views receive some support from the observations of MM. Gay-Lussac and Biot, from which it appears that the intensity of terrestrial magnetism is not diminished at the height of 13,000 feet above the earth; and Mr Henwood found the magnetic intensity as strong 710 feet above the level of the sea as at the bottom of a mine 950 feet below the same level. Kupffer, on the authority, we believe, of a single observation, has given an opposite opinion; and Saussure conceived that the intensity was less on the Col de Geant than at Geneva, but the numbers which he gives actually authorizes the opposite conclusion.

Effect of height on the intensity.

From a series of observations made in July 1830 by M. Quetelet, in Switzerland, it appears that in place of the intensity diminishing with the height, it actually increases, the increase taking place gradually (with the exception of Bonneville) in ascending from Geneva to the Col de Balme, as is shown in the following table:[1]—

	Horizontal Intensity.		Horizontal Intensity.
Geneva	1·0805	Chamouni	1·0935
Bonneville	1·0765	Col de Balme	1·0917
Sallenches	1·0815	Martigny	1·0921
St Gervais	1·0861	Hospice St Bernard	1·0966
Vaudagnes	1·0884	Simplon Village	1·0987
Servoz	1·0872	Domodossolo	1·0997
Mer de Glace	1·0885		

An argument for the atmospheric origin of terrestrial magnetism may be derived from the admitted fact, that *there actually exists in our atmosphere a powerful source of magnetism*, with which the south pole of the needle has a distinct connection. This source of magnetism is the *aurora borealis*, and the south pole of the dipping needle points to the focus to which the beams of the aurora converge. These beams act as magnets, as we have seen in a previous section; the action of our magnetic atmosphere, when undisturbed by any other cause but that of temperature, tends to fix the needle in a specific direction, which varies within certain limits, depending on the ordinary changes of temperature; but when the regular magnetism of the atmosphere is disturbed by electric or other causes, the needle must necessarily be affected by the displacement or altered temperature of the magnetic matter, as exhibited in the motions and variations in the lustre of the beams of the aurora. The magnetic pole, therefore, in our hemisphere, will be a north pole attracting the south end of the needle, and creating an elevation of the south end in place of a dip of the north end.

By the aid of these views, all the magnetic phenomena of the aurora borealis, so ably described by Dr Dalton, and the disturbances of the needle, so accurately observed by M. Arago, in reference to the auroræ that occurred in every part of the northern hemisphere, may be satisfactorily explained, as we have attempted to do in a preceding section.

Magnetic influence of the sun.

In seeking for a cause which is capable of inducing magnetism on the ferruginous matter of our globe, whether we place it within the earth or in its atmosphere, we are limited to the SUN, to which all the magnetic phenomena have a distinct reference; but whether it acts by its heat or by its light, or by specific rays, or influences of a magnetic nature, must be left to future inquiry. Without placing any reliance on the observations which have been supposed to indicate a magnetic action in the violet rays, we attach some importance to the observations of Barlocci and Zantedeschi, who found that both natural and artificial magnets had their magnetism greatly increased by exposure to the common solar rays; a result which could not arise from their heating power, as an increase of temperature invariably diminishes the power of magnets.

Dalton's views respecting the aurora.

In the work of Dr Dalton, published in 1793, to which we have already referred, there are several ingenious hypothetical views respecting the cause of the aurora borealis and its magnetic influence, with which we were not acquainted till the sections on that subject were written; but as these views strongly confirm the hypothesis of terrestrial magnetism which we have ventured to bring forward, we shall state as briefly as we can the leading ideas of Dr Dalton.

1. *The region of the aurora* is 150 miles above the earth's surface. Immediately above the earth's surface is the region of the clouds, then the region of meteors called falling stars and fire-balls, and beyond this region is that of the aurora. In proof of the great height of the aurora (independent of actual measurement) Dr Dalton adduces its extreme attenuated light, which, he says, may spread over one-half of the hemisphere, and not yield more light than the full moon. "This," he continues, "arises from the extreme rarefaction of the air, which is almost tantamount to a Toricellian vacuum; in fact, the light of the aurora exactly corresponds with that of the electric spark, when sent through a tube in which the air has been rarefied to as high a degree as can be effected by a good air-pump."

2. *The matter of the aurora.*—"From the conclusions in the preceding section," says Dr Dalton, "we are under the necessity of considering the *beams* of the *aurora borealis* of a *ferruginous* nature, because nothing else is known to

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[1] These results are not consistent with those obtained by Gay-Lussac and Biot, and by others, as mentioned in the history prefixed to this article. The careful experiments of Prof. J. D. Forbes, made on the Alps and Pyrenees, with Hansteen's intensity needles, resulted in giving a negative co-efficient to the height; and when eliminated by the method of least squares, the probable co-efficients of varied intensity for 100 feet of elevation were as follows:—

Alps, with the cylindrical needle	·000033 of the absolute intensity.
Do. flat needle	·000027
Pyrenees, with both	·000053
Probable mean	·000034

Hence, to produce a variation of ·001, an elevation of 3000 feet is necessary.

be magnetic; and consequently that there exists in the higher region of the atmosphere an electric fluid, partaking of the properties of *iron*, or rather of *magnetic steel;* and that this fluid, doubtless from its magnetic property, assumes the form of cylindric beams." "My *fluid of magnetic matter*," adds Dr Dalton in another place, "is, like magnetic steel, a substance possessed of the properties of magnetism." "Whether any of the various kinds of air or elastic vapour we are acquainted with is magnetic, I know not, but hope philosophers will avail themselves of these hints to make a trial of them."

3. *Exciting cause of the magnetism of the aurora.*—"With regard to the exciting cause of the aurora, I believe it will be found in change of temperature." "Nothing is known to affect the magnetism of steel; heat weakens or destroys it; electricity does more—it sometimes changes the pole of one denomination to that of another, or inverts the magnetism. Hence we are obliged to have recourse to one of these two agents, in accounting for the mutations above mentioned. As for heat, we should find it difficult, I believe, to assign a reason for such sudden and irregular productions of it in the higher regions of the atmosphere, without introducing electricity as an agent in these productions; but rather than make such a supposition, it would be more philosophical to suppose electricity to produce the effect on the magnetic matter *immediately.* "The beams of the *aurora* being magnetic, will have their magnetism weakened, destroyed, or inverted, *pro tempore*, by the several electric shocks they receive during an aurora."

4. *The nature of the magnetism of the beams of the aurora.*—Dr Dalton conceives the magnetism to be permanent, and not induced; and *each beam to be as it were a separate magnet*, with the regular polarity of permanent magnets. "I conceive that a beam may have its magnetism inverted, and exist so for a time, &c. . . . and I farther conceive, that when the beam is restored to its natural position of the north pole downward, it is effected, not by inverting the beam wholly as a beam (for this is never observed in an aurora), but by inverting the constituent particles, which may easily be admitted, of a fluid."

"If a magnet be required to be made of a given quantity of steel, it is found by experience to answer best when the length is to the breadth as 10 to 1 nearly. It is a remarkable circumstance, that the length and breadth of the magnetic beams of the aurora should be so nearly in that ratio. Query, if a fluid mass of magnetic matter, whether elastic or inelastic, were swimming in another fluid of equal density, and acted on by another magnet at a distance, what form would the magnetic matter assume? Is it not probable it would be that of a cylinder, of proportional dimensions to the beams of the *aurora?*

5. *Governing cause of the magnetism of the aurora.*—"As the beams," says Dr Dalton, "are swimming in a fluid of equal density with themselves, they are in the same predicament as a magnetic bar or needle swimming in a fluid of the same specific gravity with itself; but this last will only rest in *equilibrio* when in the direction of the *dipping needle*, owing to what is called the *earth's magnetism;* and as the former also rests in that position only, the effects being similar, we must, by the rules of philosophizing, ascribe them to the same cause. Hence then it follows, that THE AURORA BOREALIS IS A MAGNETIC PHENOMENON, AND ITS BEAMS ARE GOVERNED BY THE EARTH'S MAGNETISM." "I am aware that an objection may be stated to this; if the beams be swimming in a fluid of equal density, it will be said they ought to be drawn down by the action of the earth's magnetism. Upon this I may observe, that it is not my business to show why this is not the case, because I propose the magnetism of the beams as a thing demonstrable, and not as a hypothesis. We are not to deny the cause of gravity because we cannot show how the effect is produced. May I not the difficulty be lessened by supposing the beams of less density than the surrounding fluid?"

Although this brief abstract of Dr Dalton's essay contains many views which in their general bearing add to the probability of the hypothesis which we have maintained, yet we must state in a few words the difference between the two hypotheses.

1. According to our views, terrestrial magnetism resides wholly in the earth's atmosphere, which contains throughout its whole extent ferruginous and other metallic matter, and sulphureous exhalations, all of which are carried off by evaporation, by ejection from volcanoes, and by the returning strokes of electricity from the earth to the air. The actual existence of such materials in the atmosphere, particularly sulphureous and ferruginous matter, is proved by the observations of Fusinieri, and by the existence of meteoric stones and other solid substances which fall on the earth.

2. The magnetism which directs the needle is induced upon the magnetic matter in the atmosphere, like that of an iron sphere, by some exterior cause, although it is very probable that small local effects may be produced by ferruginous matter within the earth, and near its surface; but the only effect of these will be to produce small irregularities in the intensity of the magnetism of the needle, and in its direction.

3. As the colour of the electric spark, when taken from different bodies, or when passing through different media, depends on the solid matter which it renders luminous, so the different colours of lightning, of the auroral beams, of falling stars, and of meteors of every kind, are produced by the heat of the electric fluid either rendering the material substance visible by incandescence, or throwing it into a state of combustion.

4. The beams of the aurora are those portions of the magnetic atmosphere through which electricity is passing, and which, by being heated to different degrees are brought to different states of incandescence, and have their induced magnetism increased, like that of all ferruginous bodies which are brought to a temperature less than that of white heat.

Views of Mr Grover,

In his work *On the Magnetic Orbit*, already referred to, Mr Grover has expressed some new opinions on the nature and locality of terrestrial magnetism. He considers the atmosphere as its immediate source, containing within it isolated columns of conducting media, which surround the earth in such a manner, that in 365 revolutions the sun generates in it an electro-magnetic circulation. The earth's surface then becomes enveloped in a vast electro-magnetic spiral coil, and its inhabitants are thus placed between the coil and the surface by those peculiar motions of the earth which arise from the yearly cycle finding its period at different hours of the day, and on different meridians. Such a change may take place, from time to time, in the precise position of this great atmospheric coil as would correspond with the orbit of the magnetic revolution.

and of Sir W. Harris.

In reference to these views Sir W. Harris remarks, "that the phenomena of periodical variations depend evidently on the action of heat and the position of the sun, and probably in resulting thermo-magnetic currents. Beyond this mere assumption, however, we have no very secure basis for reasoning. The most admissible view, however, of this kind of action, is the following:—During the daily motion of the earth, its surface, especially about the tropics, is successively heated and cooled in successive points, and in an E. and W. direction. Then if we admit that thermo-magnetic currents are thus excited (as in Dr Seebeck's experiment of heating a combination of antimony and bismuth bars at one point, and cooling them at another), and that they circulate in an E. and W. direction over the earth's surface, the result will be a magnetic development in a N.

and S. direction, and hence there will be a magnetic development in a direction nearly parallel with its axis."[1]

The opinion that magnetism resides wholly or to a great extent in our atmosphere, has been rendered more probable by the important discovery of Dr Faraday, that oxygen gas, which composes two-ninths of the atmosphere by weight, is magnetic like iron, while nitrogen has no such property. Hence it is to the magnetic constitution and condition of the atmosphere, and the changes effected in it by variations of temperature and pressure, winds, currents, rain and snow, &c., that Dr Faraday refers the annual and diurnal variation of the needle.

Although it is universally admitted that a source of magnetism has been proved to exist in our atmosphere, and though it is evident that the force which emanates from it is greater than any magnetic force which can be proved to have its origin in the solid part of the earth, yet it may be asked if there is any reason for believing that the magnetism in the atmosphere is strong enough to be considered as the only source of terrestrial magnetism? To this question, some of the facts already stated afford a pretty satisfactory answer. M. Arago showed that the auroræ which exist only at St Petersburg, in Siberia, and even in North America, actually disturb the magnetic needle at Paris; and he considered it highly probable that the auroræ even round the south pole of our globe extend their influence to Paris. If a force of such magnitude exists in insulated beams which form regular magnets, according to Dr Dalton, we need not scruple to suppose that a ferruginous atmosphere is capable of producing that degree of intensity which characterizes terrestrial magnetism, and that the disturbances exhibited at Paris on the magnetic needle are the effect of local diminutions or augmentations of the magnetic force in Siberia, America, or even in the southern hemisphere.

CHAP. X.—ACCOUNT OF THE DIFFERENT METHODS OF MAKING ARTIFICIAL MAGNETS.

Methods of making artificial magnets.

In the "History of Magnetism" we have already made a brief reference to the principal methods of making artificial magnets. We shall now proceed to give a short account of the methods themselves.

In the infancy of the science, a bar B of hard steel was magnetized by rubbing it throughout its whole length on one of the poles N of a natural or artificial magnet A, in a direction at right angles to the line joining the two poles of the primitive magnet. By this process the new bar *a* will be rendered slightly magnetic, but its magnetism cannot possibly be completely developed unless in the two cases where the new bar is extremely small, or the primitive magnet A extremely powerful; and the magnetism which is communicated often exhibits different poles, or consequent points as they are called, throughout the length of the new bar.

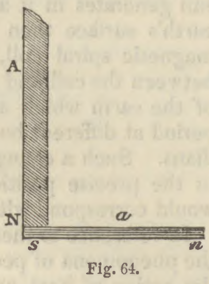

Fig. 64.

In using this method, the exciting pole should be slightly pressed upon the new bar; and after reaching the end of the bar at *s*, it must be lifted up and applied again to the other end, the friction being always made in the same direction.

Another old method of making magnets consisted in placing the end *s* of a new bar B *in contact* merely with one of the poles N of a powerful magnet, and striking the new bar so as to make it ring during the time of its application. This method, however, like the first, will be effectual only for very small bars; the pole *s* will be the strongest, and the neutral point at B will be nearer *s* than *n*.

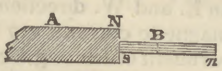

Fig. 65.

A more efficacious method of magnetizing small bars by simple contact is shown in the annexed figure, by placing the new bar B between the opposite poles N, S of two strong magnetic bars A, A', of nearly equal power. In this case the magnetism of B will be nearly twice as great as when only one, A or A', is used; and if there are no consecutive poles produced the neutral point B will bisect *ns*.

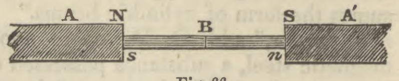

Fig. 66.

These simple methods were discontinued when the principles of magnetic induction were better understood, and several ingenious and highly effective processes of making artificial magnets were invented by the philosophers of the eighteenth century. The first of these was that of Mr Knight.

SECT. I.—*Account of Dr Gowin Knight's method of making Artificial Magnets.*

Knight's method.

Dr Gowin Knight, a physician in London, was long celebrated for the excellence of the artificial magnets which he made, and some of which he presented to the Royal Society. The method which he used was kept a secret during his life, but was published after his death by Mr Wilson.

The bar or needle B, which he intended to magnetize, was tempered at a *cherry-red heat*, and placed under the opposite poles N, S of two equal magnets. These magnets are then separated in opposite directions SA', NA, so that the south pole S of the one passes over the *north-polar* half B*n* of the bar B, and the north pole N of the other, over the *south-polar* half B*s* of B. This operation is repeated several times, till the magnetism of the bar B is fully developed.

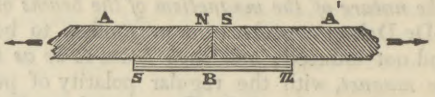

Fig. 67.

In this process the north pole N, while it attracts to the half B*n* all the south-polar magnetism in B*s*, repels at the same time into B*s* all the north-polar magnetism of B*n*. The same is true, *mutatis mutandis*, with the south pole S. When the bars A, A' are large and powerful, it has been found that this process is capable of communicating to small bars all the magnetism of which they are susceptible. (See *Phil. Trans.*, vol. xliv., 1746–47).

By this process Dr Knight constructed a magnetic machine of great power, with the view of developing in steel

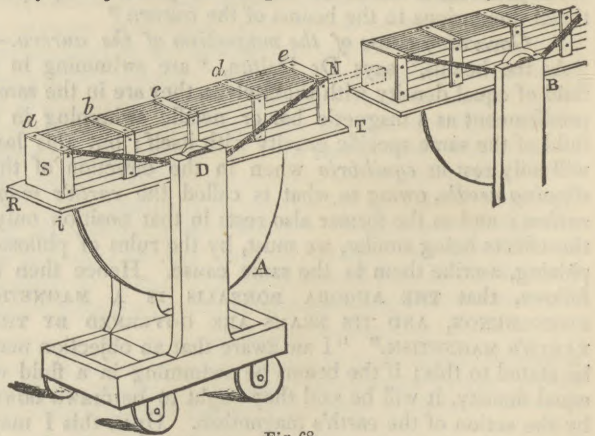

Fig. 68.

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[1] *Rudim. Mag.* iii. 119.

needles a very intense degree of magnetism. This machine consisted of 480 bar-magnets, each 15 inches long, 1 inch wide, and half an inch thick, arranged in two separate magazines, having 240 magnets in each; one of these magazines is represented in the annexed figure at SN. The bars were arranged in four lengths *ab*, *bc*, *cd*, and *de*, having their north poles turned the same way, and consequently their dissimilar poles in contact. Each bundle *ab* contained 60 bars, arranged in six beds of 10 bars each, set edgewise, so that there were 10 bars in width and 6 in depth. Each magazine weighed 500 lb., and was mounted on rollers as in the figure. Dr Robison saw this machine about the year 1800, and described the effect of pressing together the dissimilar poles of the two magazines as if one were pressing against a feather bed. Dr Faraday examined them in 1830. Upon placing a cylinder of soft iron 1 foot long and $\frac{3}{4}$ths of an inch in diameter across the dissimilar poles, a force of 100 lb. was necessary to overcome the attractive force.

SECT. II.—*Account of Duhamel's method of making Artificial Magnets.*

Duhamel's method.

After Dr Knight's process had been known and used, the artificial magnets which were made by it were in great request, and distributed throughout Europe. When the process, however, was applied to bars of great size, it was found to be defective; and M. Duhamel of the Academy of Sciences, in conjunction with M. Antheaume, set themselves to devise a better method, which is represented in the annexed figure. The bars B, B′ to be magnetized are placed parallel to each other, and have their extremities united by two pieces M, *m* of soft iron, at right angles to the bars. He then took two strong magnets A, A′, or two bundles of small bar-magnets, the bars of each bundle having their similar poles together; and having placed them, as in the figure, at an angle of about 90°, or inclined 45° to the bar B, they were separated from each other, as already described in the explanation of figure 67. The same operation was repeated on the other bar B′, and continued alternately on both till the magnetism was supposed to be completely developed in both bars. When A and A′ are placed upon the second bar B′, the disposition of the poles must be reversed, the pole that was formerly to the right hand being now placed to the left. The two bars B, B′ are then turned, so that the undermost faces are uppermost, and the same process carried on as before.

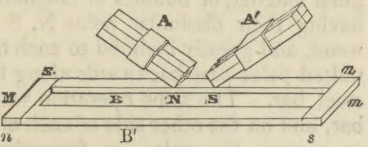

Fig. 69.

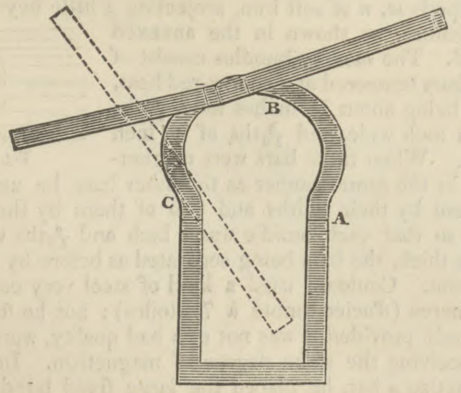

Fig. 70.

The distinctive peculiarity of Duhamel's process consists in the employment of the pieces of iron M, *m*, and in the use of bundles of small bars, which are more efficacious than two single ones of the same size.

The very same method is applicable to curved bars, or those of the horse-shoe form, as shown in fig. 70, where the inclined bars are carried round the curved bar ABC, exactly as they were along the straight bar B.

SECT. III.—*Account of Mr Michell's method of making Artificial Magnets.*

Michell's method of double touch. A.D. 1750.

About the same time that Duhamel was occupied with this subject, Mr Michell of Cambridge, and Mr Canton, were separately engaged in the same inquiry. Mr Michell published his method in 1750, to which he gave the name of the *method of double touch*. Having joined together, at the distance of a quarter of an inch, two bundles of strongly magnetized bars A, A′ (fig. 71), their opposite poles N, S being together, he placed five or more equal steel bars B, B′, B′, B″, B″ in the same straight line; and resting the extremity of the bundle of magnets A, A′ upon the middle of the central bar B, he moved them *backwards* and *forwards* throughout the whole length of the line of bars, repeating the operation on each side of the bars, till the greatest possible effect was produced. By this method Mr Michell found that the middle steel bars B, B′, B′, acquired a very high degree of magnetic virtue, and greater than the outer bars B″, B″; but by placing these last bars in the middle of the series, and repeating the operation, they acquired the same degree of magnetism as the rest.

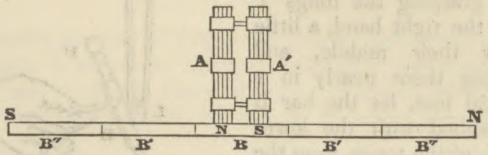

Fig. 71.

Mr Michell states, that two magnets will, by his process of double touch, communicate as strong a magnetic virtue to a steel bar, as a single magnet of five times the strength, when used in the process of single touch. The bars A, A′ act with the sum of their powers in developing magnetism in all parts of the line of bars between them, and with the difference of their powers in all parts of the line of bars beyond them. The external bars act the same part in this process as the two pieces of soft iron in the method of Duhamel.

SECT. IV.—*Account of Canton's method of making Artificial Magnets.*

Canton's method.

In the year 1751 Mr Canton published his process, which he regarded as superior to preceding ones. He placed the bars as in Duhamel's method, joined by pieces of soft iron. He then applied Michell's method of double touch, and afterwards he separated the two bundles of magnets A, A′, and having inclined them to each other, as in Duhamel's method, he made them rub upon the bar from the middle to its extremities. The peculiarity of Canton's method is the union of these two processes; but Coulomb and others have regarded the latter part of the process as the only effectual one.

Without natural or artificial magnets.

In order to make artificial magnets without the aid either of natural loadstones or artifical magnets, Mr Canton gives the following detailed process:—

He takes six bars of soft and six of hard steel, the former being smaller than the latter. The bars of *soft* steel should be 3 inches long, $\frac{1}{4}$th of an inch broad, and $\frac{1}{20}$th thick; and two pieces of iron must be provided, each having half the length of one of the bars, and the same

Methods of making Artificial Magnets.

breadth and thickness. The bars of *hard* steel should be each 5½ inches long, ½ inch broad, and $\frac{3}{20}$ths of an inch thick, with two pieces of iron of half the length, and the same breadth and thickness.

All the bars being marked with a line quite round them at one end, take an iron poker and tongs, or two bars of iron, the larger and the older the better, and fixing the poker P upright, as in fig. 72, hold to it with the left hand, near the top P, by a silk thread, one of the *soft* bars B, having its marked end downwards; then grasping the tongs T with the right hand, a little below their middle, and keeping them nearly in a vertical line, let the bar B be rubbed with the lower end L of the tongs, from the marked end of the bar to its upper end, about ten times on each side of it. By this means the bar B will receive as much magnetism as will enable it to lift a small key at the marked end; and this end of the bar being suspended by its middle, or made to rest on a point, will turn to the *north*, and is called its *north* pole, the unmarked end being the *south* pole.

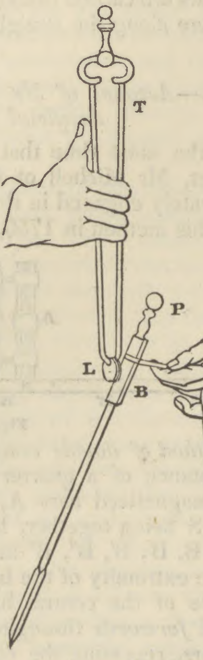

Fig. 72.

When four of the soft-steel bars are thus rendered magnetic, the other two AC, BD (fig. 73), must be laid parallel to each other, at the distance of about ¼th of an inch, as in the figure, having their dissimilar poles united with the smallest pieces of iron AB, CD. Two of the magnetized bars are then to be placed together, as at G, with their similar poles united, and the other two as at K; and when separated by a piece of wood I, they are slid four or five times backwards and forwards along the whole length of the bar AC, so that the marked end F of G is nearest the unmarked end of AC, and *vice versa*. This operation is carefully repeated on BD, and on the other sides of both AC and BD. When this is done, the bars AC, BD are to be taken up and substituted for the two outer bars of the bundles G, K, these last being laid down in the place of the former, and magnetized in a similar manner. This operation must be repeated till each pair of the soft bars has been magnetized *three* or *four* times.

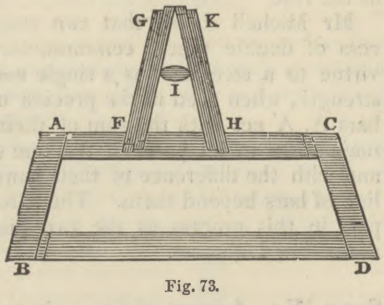

Fig. 73.

When the six soft bars are thus magnetized, they must be formed into two bundles of three each, with their similar poles together, and must be used to magnetize two of the *hard* bars in the manner already described; and when they are magnetized, other two of the hard bars must be touched in a similar manner. The soft bars are now to be laid aside, and the remaining two hard bars magnetized by the *four* hard bars already rendered magnetic; and when this is done, the operation should be repeated by interchanging the hard bars, till they are impregnated with the greatest degree of permanent magnetism which this method is capable of communicating to them.

Methods of making Artificial Magnets.

In performing the above operations, which may be completed in about half an hour, the bars AC, BD, and the pieces AB, CD should be placed in grooves, or fixed between pins of wood or brass, to keep them steady during the successive frictions which are applied to them. According to Canton, each of the six artificial magnets thus made will lift about 28 ounces troy. They should be kept in a wooden box, and placed as in the annexed figure, so that no two poles of the same name may be together, and the pieces of iron AB, CD (fig. 74) placed beside them.

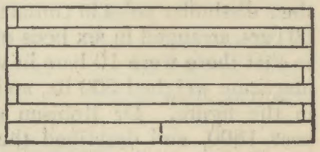
Fig. 74.

SECT. V.—*Account of Æpinus's method of making Artificial Magnets.*

Æpinus's method.

The method of magnetizing steel bars by the double touch was greatly improved by Æpinus. In place of the pieces of iron M, *m*, used by Duhamel, he used magnets, and formed the rectangle with the two steel bars to be magnetized, having their extremities united by two magnets M, *m*, placed as in figure 69. He then placed the original magnet, or bundles of magnets A, A′, as in the figure, having their dissimilar poles N, S separated by a piece of wood, and greatly inclined to each other; and he made the united poles pass backwards along the whole length of the steel bar. The same operation was repeated on the other bar, and on the other side of each of them, care being taken to reverse the poles, as formerly mentioned, when the rubbing bars are removed from the one steel bar to the other. Æpinus found that a maximum effect was produced when the bars A, A′ were inclined 20° or 30° to the steel bar over which they passed.

SECT. VI.—*Account of Coulomb's method of making Artificial Magnets.*

Coulomb's method.

The method of making artificial magnets employed by Coulomb consists of the most efficacious parts of the preceding processes, improved and extended by long experience in the art. The apparatus which he uses consists of *fixed* and *moving* bundles of magnets. Each of the fixed bundles consists of *ten* bars of steel tempered at a cherry-red heat, their length being about 21 inches, their breadth $\frac{6}{10}$ths of an inch, and their thickness ⅛th of an inch. Having rendered them as strongly magnetic as possible, with a natural or an artificial magnet, he joined them with their similar poles together, and formed them into two beds of four bars each, these beds being separated by small rectangular parallelopipeds *m*, *n* of soft iron, projecting a little beyond their extremities, as shown in the annexed fig. 75. The *moving* bundles consist of four bars tempered at a cherry-red heat, each being about 16 inches long, $\frac{6}{10}$ths of an inch wide, and $\frac{2}{10}$ths of an inch thick. When these bars were magnetized in the same manner as the other bars, he united two of them by their widths and two of them by their thickness, so that each bundle was 1 inch and $\frac{2}{10}$ths wide, and $\frac{4}{10}$ths thick, the bars being separated as before by pieces of soft iron. Coulomb used a kind of steel very common in commerce (d'acier timbré à 7 etoiles); but he found that all kinds, provided it was not of a bad quality, were capable of receiving the same degree of magnetism. In order to magnetize a bar, he placed the large fixed bundles M, N in the same straight line, and at a distance a little less than the length of the bar to be magnetized; and this bar BB′

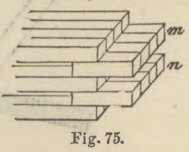

Fig. 75.

Methods of making Artificial Magnets.

was placed, as in fig. 76, so as to rest on the projecting pieces of iron, so that the contact took place only over a length of $\frac{1}{6}$th of an inch; the two moving bundles A, A′ having their dissimilar poles separated by a small piece of wood or copper about $\frac{1}{5}$th of an inch wide between them, and each being inclined at an angle of 20° or 30° to the bar BB′. The united poles of the moving bundles are then moved successively from the centre to each extremity of the bar BB′, so that the number of frictions upon each half of the bar may be equal. When the last friction has been given, the united poles are brought to the middle point of the bar BB′, and then withdrawn perpendicularly. The same operation is then repeated on the other side of the bar BB′. If we wish to employ the method of Duhamel in place of that of Æpinus, we do not require the piece of wood or copper, but have only to separate the bars when their united poles are in the middle of the bar BB′, making each pole pass to the extremity of it.

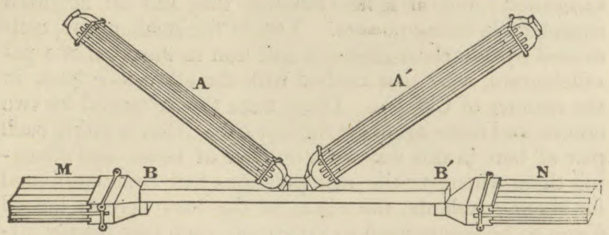

Fig. 76.

When the fixed and moving bundles are composed of bars which have not been magnetized to saturation, we must form new bundles with the newly magnetized bars, whose magnetism will be stronger than those by which they were magnetized, and by their means magnetize anew the bars first used; and by repeating this process three or four times, the bars may be raised to the highest degree of magnetic virtue.

When the bars BB′ to be magnetized are very large, the moveable bundle should contain more than four bars, each of the bars retreating about half an inch in the direction of their thickness, as shown in the annexed figure. The advantage of this displacement arises from the fact, that the highest degree of magnetism resides in the extremity of the bar. Hence, by this arrangement, not only the most efficacious parts of the moving bar are brought into contact with the bar to be magnetized, and act more powerfully, but the bar nearest to the central one in the bundle tends not merely to maintain, but to augment, in its extremity, its degree of magnetism. The third bar produces the same good effect upon the second, and so on with the rest.

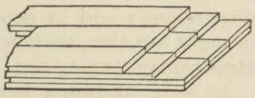

Fig. 77.

SECT. VII.—*Account of M. Biot's method of making Artificial Magnets.*

Biot's method.

M. Biot proposed several important improvements on the process of Coulomb. As the bars are always bent a little in tempering, he recommends that they should at first be brought to as hard a temper as possible, and then annealed to the first shade of yellow. By this means they will have a sufficient degree of malleability to be again brought into shape, while they possess sufficient coercive power for receiving and retaining a high degree of magnetism. Regarding it as of essential importance to insure an intimate contact between the plates of the large bundles and the soft iron or armour by which they are united, Biot formed his armour of several plates of very soft iron, which cover the elementary plates at that part of their extremities where the repartition of free magnetism is perceptible. These plates of soft iron form part of a mass of the same nature terminating in the form of a trapezoid, as shown in the annexed figure, and the plates of steel are inserted in it, as shown by the dotted lines; so that the plates which lie in the axis of the bundles project a little beyond the lateral plates. The whole is then bound together with a collet of soft iron, held firmly by a screw. Biot remarked, that he has found from experience that this arrangement, indicated by theoretical considerations, is extremely advantageous.

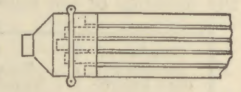

Fig. 78.

Methods of making Artificial Magnets.

Coulomb's method of arming magnets.

Coulomb's method of fitting up, arming, and preserving his magnets is shown in the annexed figure, representing two artificial magnets, armed at their extremities with two iron parallelopipeds, N, S, N′, S′; N, N′ being the north poles, and S, S′ the south poles. These parallelopipeds have their inner ends enveloped within the magnetic bars. The opposite poles N, S′, N′, S, are joined by pieces of soft iron, A, B, and the bars of each magnet are held together by the upper bands *a*, *b*, *a*′, *b*′.

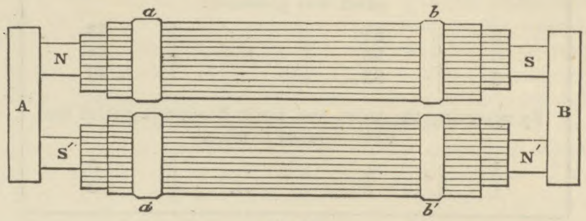

Fig. 79.

With an apparatus of this kind, each part weighing 15 or 20 pounds, 80 or 100 pounds is required to separate the pieces A, B from the poles, and an ordinary needle is magnetized to saturation by merely placing it upon the ends N, S′ or N′, S.

SECT. VIII.—*Account of Dr Scoresby's method of making Artificial Magnets.*

Scoresby's method.

A very simple and efficacious method of making artificial magnets by percussion was published by Dr Scoresby.[1] That iron became magnetic when struck by successive blows of a hammer in the direction of the dipping needle, was known to Dr Gilbert, and also to M. Du Faye and Dr Desaguliers;[2] but it is to Dr Scoresby that we owe a complete investigation of the subject. In order to determine the effects produced by percussion, Dr Scoresby used two methods, the one by observing the weight which the new magnet lifted, and the other by measuring the deviation which it produced on a magnetic needle. The following experiments were made with a cylindrical bar of soft steel $6\frac{1}{2}$ inches long, $\frac{1}{4}$th of an inch in diameter, and weighing 592 grains. It was placed in a vertical position, resting on a piece of tin, and struck with a hammer of 12 ounces.

Number of Strokes at each Experiment.	Total Number.	Weight suspended by the Bar.	Deviation of the Needle; distance of Needle, three inches.
1	1	2 grs.	8°
1	2	0	10
5	7	4	12
10	17	6½	12½
5	22	6½	12½

When the steel bar was placed upon a stone, the effect

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[1] *Phil. Trans.*, 1822, part ii., p. 241.

[2] *Phil. Trans.*, 1738.

Methods of making Artificial Magnets.

was the same; but, as the following experiments show, a great increase of power was obtained by supporting the lower end of the bar upon the upper end of a large bar of iron or soft steel. The hammer weighed 12 ounces, and the distance of the needle was 3 inches.

Number of Strokes at each Experiment.	Total Number.	Weight suspended by the Bar.	Deviation of the Needle.
1	1	6½ grs.	13°
1	2	14	16
1	3	...	18
4	7	37	21
5	12	45	25
10	22	88	27
20	42	88	30
30	72	...	31
10	82	...	31½
By using a hammer weighing 22 ounces, an increased effect was produced.			
3	85	...	33
5	90	130	34
3	93	...	30
By reversing the poles, and again hammering with the twelve-ounce hammer.			
1	...	...	5
1	2	...	2

From these experiments it follows, that a cylindrical bar of soft steel, weighing 592 grains, can be made to lift only 6½ grains, when struck in a vertical position, with its lower end resting upon tin or stone; whereas the same bar, when struck with twenty-two blows upon a rod of iron suspended at its lower end, which was a north pole, lifted 88 grains; by using a larger hammer, its lifting power increased to 130. When the steel bar was reversed, so that its south pole was uppermost, its magnetism was almost destroyed by a single blow, and two blows were sufficient to change its poles. Dr Scoresby found that when the steel magnet was struck in the plane of the magnetic equator, its polarity also disappeared; but several blows were necessary to effect this change.

In another set of experiments on the effect of percussion on magnets, he employed a flat bar-magnet $7\frac{7}{10}$th inches long, ½ inch wide, $\frac{1}{7}$th thick, and weighing 1170 grains.

When suspended vertically, with its south end uppermost, it produced, at the distance of 8 inches, a deviation of 45° on the needle; but after sixty, eighty, and a hundred blows, the deviation was reduced to 25°.

When the north pole was placed uppermost, other thirty blows reduced the deviation still farther, from 25° to 14°.

When the bar was again magnetized, and hammered upon a piece of tin, it produced a deviation of 50°; but after twenty blows, with the south pole uppermost, the deviation became 33°. By other sixty blows, with the north pole uppermost, the deviation became 24°.

From the results obtained in the preceding experiments, Dr Scoresby deduced the following method of making artificial magnets by percussion:—

"I procured two bars of soft steel 30 inches long and 1 inch broad, also six other flat bars of soft steel 8 inches long and ½ inch broad, and a large bar of soft iron. The large steel and iron bars were not, however, absolutely necessary, as common pokers answer the purpose very well; but I was desirous to accelerate the process by the use of substances capable of aiding the development of the magnetical properties in steel. The large iron bar was first hammered in a vertical position; it was then laid on the ground with its acquired south pole towards the south, and upon this end of it the large steel bars were rested while they were hammered; they were also hammered upon each other. On the summit of one of the large steel bars, each of the small bars, held also vertically, was hammered in succession; and in a few minutes they had all acquired considerable lifting powers. Two of the smaller bars, connected by two short pieces of soft iron in the form of a parallelogram, were now rubbed with the other four bars, in the manner of Canton. These were then changed for two others, and these again for the last two. After treating each pair of bars in this way for a number of times, and changing them whenever the manipulations had been continued for about a minute, the whole of the bars were at length found to be magnetized to saturation, each pair readily lifting above 8 ounces.

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"In accomplishing this object, I took particular care that no magnetic substance was used in the process. All the bars were freed of magnetism before the experiment, so that none of them, not even the largest, produced a deviation of five degrees on the compass at 3 inches distance. Any bars which had been strongly magnetized, and had had their magnetism destroyed or neutralized (either by hammering, heating, or by the simultaneous contact of the two poles of another magnet placed transversely), I always found had a much greater facility for receiving polarity in the same direction as before, than the contrary. Hence it generally happened that one blow with the original north end downwards, produced as much effect as two or three blows did with the original south end downwards."

By this ingenious process, any person who has no magnets within his reach may communicate the strongest degree of permanent magnetism to hard steel bars of any magnitude, the bars magnetized by percussion being employed, as in the process of Coulomb, to magnetize the large bars which are required.

Sect. IX.—*Method of making Horse-Shoe Magnets.*

Method of making horse-shoe magnets.

Horse-shoe magnets are those which have the form of a horse-shoe, as shown in fig. 70; and this form is, generally speaking, the most convenient for use, and for the preservation of their magnetic power. In all experiments where a large weight is to be lifted, the horse-shoe magnet is indispensable; and in consequence of the two poles being brought together, they may be substituted with great advantage for magnetizing steel bars by the method of double touch.

In order to form a powerful magnetic battery, the best way is to unite a number of similar horse-shoe magnets, with their similar poles together, and to fix them firmly together in a case of copper or leather. The following is the method recommended and used by Professor Barlow:—

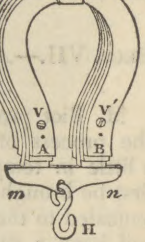

Fig. 80.

He took bars of steel 12 inches long, and having bent them into the horse-shoe shape, their length was 6 inches, their breadth 1 inch at the curved part, and ¾ths of an inch at their extremities, and their thickness ¼th of an inch. They were filed very nicely, so as to correspond, and lie flatly upon each other. They were then drilled with three holes in each, as seen in the figure, and by means of screws V, V' passing through these holes, *nine* horse-shoe bars were bound together. When the heads and ends of the screws were constructed so as to leave the outer surfaces smooth, the mass of bars was filed as if they were one piece, and the surface made flat and smooth. When the bars were separated, they were carefully hardened, so as not to warp, and when they had been well cleaned and rendered bright, but not polished, they were magnetized separately in the following manner:—When the two extremities of the bar are connected by a piece of soft iron M (fig. 81), the magnetism may be developed in the two

Methods of making Artificial Magnets.

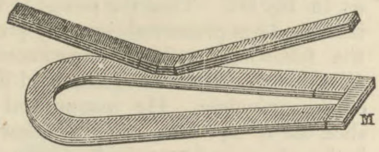

Fig. 81.

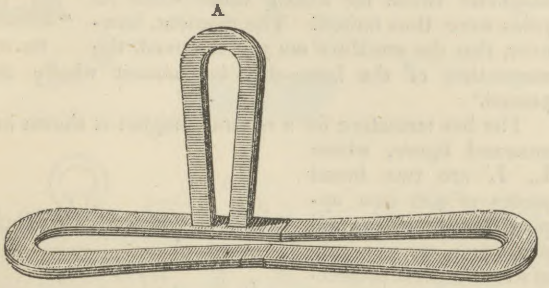

Fig. 82.

halves by Duhamel's method, as in fig. 81; or, following Æpinus, we may apply a strong magnet to each pole, and connect their extremities either with a piece of soft iron or another magnet; or we may apply two horse-shoe magnets to each other, as in fig. 82, uniting the poles which are to be of contrary names. When the magnet or magnets are prepared in any of these ways, they are then to be magnetized with another horse-shoe magnet A, by placing its north pole next to what is to be the south pole of one of the horse-shoe bars, and then carrying the moveable magnet round and round, but always in the same direction. In this way a very high degree of magnetic virtue may be communicated to each of the *nine* bars. When this is done, they are to be reunited by the screws, and their poles or extremities connected by a piece of soft iron, or *lifter*, or *armature, mn*, as in fig. 80, having at its middle a hook H for suspending any weight. As the lifting power depends on the accurate contact of the poles of the magnets with the lifter, the extremities should, after hardening, be properly rubbed down with putty upon a flat surface.

A magnet of this size and form was found by Professor Barlow to suspend *forty pounds;* but he afterwards found that a greater proportional power could be obtained by using bars that were long in comparison with their breadth.

SECT. X.—*Account of Professor Barlow's method of magnetizing a number of Rectilineal Bars with a Horse-Shoe Magnet.*

Barlow's method of magnetizing bars.

The following method of making artificial magnets is both a simple and efficacious one, and was practised successfully by Professor Barlow:—Having occasion for thirty-six magnets, 12 inches long, $1\frac{1}{4}$ broad, and $\frac{1}{16}$ths of an inch thick, he placed thirty-six bars of steel, of these dimensions, on a table, so as to form a square, having nine bars on each side, the marked or north pole of each bar being in contact with the unmarked or south pole. At the angular points of the square the inner edges of the bars were brought into contact, and the external opening thus left was filled up by a piece of iron $1\frac{1}{4}$th inch square and $\frac{1}{16}$ths of an inch thick. The horse-shoe magnet described in the preceding section was set upon one of the bars, so that its north pole was towards the unmarked end of the bar, and was then carried or rubbed along the four sides of the bars; and the operation was continued till the horse-shoe magnet had gone twelve times round the square. Without removing the magnet, each bar was turned one by one, so as to turn their lower sides uppermost, and the horse-shoe magnet was made to rub along the four sides of the square other twelve times. The bars were then highly magnetized; and the whole process did not occupy more than half an hour.

Methods of making Artificial Magnets.

SECT. XI.—*Account of Knight's method of forming Artificial Magnets with an Iron Paste.*

Knight's artificial magnets of paste.

Although the following method of making a magnetic paste has been given in almost every treatise on magnetism, and was kept a secret by its inventor, yet we have no distinct information that it has been found superior in any respect to steel as a vehicle of magnetism. Mr Benjamin Wilson communicated the method to the Royal Society after the death of Dr Knight.

"Having provided himself with a large quantity of clean filings of iron, Dr Knight put them into a tub that was more than one-third full of clean water; he then, with great labour, worked the filings to and fro for many hours together, that the friction between the filings of iron by this treatment might break off such small parts as would remain suspended in the water for some time; the obtaining of which very small particles in sufficient quantity seemed to him to be one of the principal desiderata in the experiment. The water being by this treatment rendered very muddy, he poured it into a clean earthen vessel, leaving the filings behind; and when the water had stood long enough to become clean, he poured it out carefully, without disturbing such of the iron sediment as still remained, which was now reduced to an almost impalpable powder. This powder was afterwards removed into another vessel, in order to dry it; but as he had not obtained a proper quantity of it by this first step, he was obliged to repeat the process many times. Having at last procured enough of this very fine powder, the next thing to be done was to make a paste of it, and that with some vehicle which could contain a considerable quantity of the phlogistic principle. For this purpose he had recourse to linseed oil in preference to all other fluids. With these two ingredients only he made a stiff paste, taking particular care to knead it well before he moulded it into convenient shapes. Sometimes, while the paste continued in its soft state, he would put the impression of a seal on several pieces, one of which is in the British Museum. This paste was then put upon wood, and sometimes on tiles, in order to bake or dry it before a moderate fire, at about a foot distance. The doctor found that a moderate fire was most proper, because a greater degree of heat made the composition frequently crack in many places.

"The time necessary for baking this paste was generally five or six hours before it attained a sufficient degree of hardness. When that was done, and the several baked pieces were become cold, he gave them their magnetic virtue in any direction he pleased, by placing them between the extreme ends of his magazine of artificial magnets for a few seconds or more, as he saw occasion. By this method the virtue they acquired was such, that when any one of these pieces was held between any of his best ten-guinea bars, with its poles purposely inverted, it immediately of itself turned about to recover its natural direction, which the force of these very powerful bars was not sufficient to counteract."[1] After giving the preceding method, M. Biot remarks, that it consists in procuring a very fine powder of iron a little oxidated, all the particles of which he united by means of linseed oil, or any other substance fitted to give them a proper degree of oxygenation. "When this paste was magnetized," he continues, "each particle of the powder became a small magnet, in which the development of the magnetism might be very powerful, on account of the suitable degree of coercive power produced by the oxy-

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[1] *Phil. Trans.*, 1779, vol. lxix., p. 51.

Methods of making Artificial Magnets.

genation; and the homogeneity of this state in all the particles, as well as their extreme tenuity, might give to the whole system the most favourable arrangements for receiving a high degree of magnetism." M. Biot conceives that a somewhat analogous effect might be obtained by steel of an equal and homogeneous grain, the carbon giving a coercive power like oxygen; but he thinks that the paste is likely to form better magnets. He is of opinion also that some powerful natural magnets may owe their virtue to the union of similar qualities.

Dr Fothergill, who had seen Dr Knight's paste magnets in his own possession, says that the mass had the appearance of a piece of black lead, though less shining. He informs us also of a very remarkable fact, if it be true, that while the poles of a natural loadstone, or of the hardest steel magnet, could be changed, those of the paste magnets were immoveable. A small piece, of about half an inch square and one-fourth thick, was powerfully magnetic though unarmed; and its poles could not be altered though it was placed between two of Mr Knight's largest and most strongly impregnated magnetic bars.[1]

Conceiving that the powder which formed the basis of this paste was the *black oxide of iron*, or *martial Ethiops*, M. Cavallo has given the following receipt for imitating natural magnets; but he does not say that the magnets made by it are better than those of steel:—"Take some martial Ethiops reduced into a very fine powder, or, which is more easily procured, *black oxide of iron*, the scales which fall from red-hot iron when hammered, and are found abundantly in smiths' shops. Mix this powder with drying linseed oil, so as to form it into a very stiff paste, and shape it in a mould so as to give it any form you require, whether of a terella, a human head, or any other. This done, put it into a warm place for some weeks, and it will dry so as to become very hard; then render it magnetic by the application of powerful magnets, and it will acquire a *considerable* power."

The idea of constructing magnets in this manner may have been suggested by a fact described in the *Memoirs of the Academy of Science* for 1731. A bell, about 400 years old, was suspended at Marseilles by an iron axis resting on stone blocks. Great quantities of rust were thrown off from this axis from time to time, and these particles mixing with those of the stone and the oil which lubricated the pivots, formed a hardened mass which had all the properties of a native magnet.

SECT. XII.—*Account of the method of Arming and Preserving Natural and Artificial Magnets.*

On arming and preserving magnets.

We have already stated, that when a piece of soft iron is suspended at the pole of a magnet, this piece of iron is rendered magnetic, and that a second and a third smaller piece of iron suspended from the other piece of iron also become magnetic, the magnet developing magnetism in the first piece of iron, the first piece developing it in the second, and so on. Each piece of iron reacts as a magnet on the larger piece on which it hangs, improving or increasing the development of its magnetism. Hence the lifting power of a magnet may be increased by suspending to one of its poles, day after day, a small additional piece of iron.

On this property is founded the method of arming natural and artificial magnets, for the purpose both of increasing and preserving their magnetic power. In order to support the greatest weight with any magnet, both its poles should be brought into action. In the horse-shoe magnet this is easily done, so that the *armature* for it is made by merely placing a piece of soft iron *mn* upon its poles A (north) B (south), having a hook attached to it for hanging on weights, as in fig. 80. That the power of this magnet is not only increased but preserved, is easily proved; but the following striking experiment of Mr Watkins affords the most beautiful illustration of the principle. He magnetized a horse-shoe bar *of soft iron*, made of a bar nineteen inches long and one inch square, when its poles A, B were joined by another piece of iron *mn*, and he found that it preserved its magnetic virtue for a long time[2] while its poles were thus united. The moment, however, that the armature *mn* was removed, the magnetism of the horse-shoe bar almost wholly disappeared.[3]

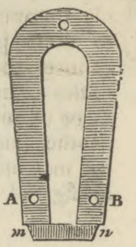

Fig. 83.

Methods of making Artificial Magnets.

The bes tarmature for a natural magnet is shown in the annexed figure, where L, L′ are two broad pieces of soft iron applied to the poles, and projecting on one side of it. To these projecting ends or transferred poles A, B, a piece of iron *mn* is applied, so as to touch them both, as in the horse-shoe magnet in fig. 80. The lateral pieces of iron L, L′ are commonly held firm to the magnet by means of a box of brass, silver, or copper, *ccc′c′*, and the magnet is then said to be armed, the pieces of iron L, L′, A, B, constituting its arms or armature.

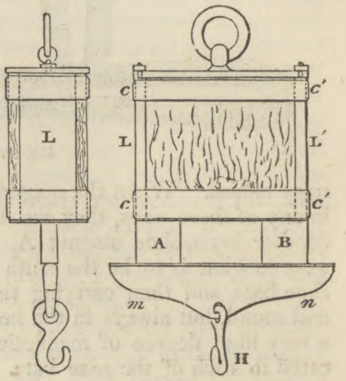

Fig. 84.

A loadstone armed in the preceding manner may be strengthened by Professor Barlow's method of magnetizing horse-shoe magnets; and if we suspend a scale or bag from the hook H, and add, day after day, some additional weight, it may be made to suspend *two* or *three* times the weight that it could lift if applied to it at once. If its force, however, is overpowered by too great a load, its strength will revert to what it was at first; but if we take out of the scale a certain part of the load which it can suspend, we may again proceed to add more weight gradually, till it carries its maximum load.

In order to preserve loadstones and magnets, their armature should always be applied to them. They should be kept in a cool place, free from vibrations, and rough treatment of every kind. Bar-magnets should always be kept with their dissimilar poles together; and both single magnets and needles will have their power not only preserved, but increased, by keeping them surrounded with a mass of dry filings of soft iron, each particle of which will react, by its induced magnetism, upon the point of the magnet to which it adheres, and maintain in that point its primitive magnetic state.

SECT. XIII.—*Account of the method of making Temporary Bar-Magnets of Soft Iron under the influence of Electric Currents.*

Electro-magnets.

In our history of ELECTRICITY we have given some account of the discoveries of M. Arago, Sir H. Davy, M. Savary, and others, relative to the communication of magnetism to steel by ordinary electricity. The subject will be resumed under the article VOLTAIC ELECTRICITY; but, without anticipating what properly belongs to that science,

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[1] *Phil. Trans.*, vol. lxvi.

[2] See the following section.

[3] *Phil. Trans.*, 1833, p. 338.

Methods of making Artificial Magnets.

we shall give an account in this section of the method of making bar-magnets of soft iron by the influence of electric currents.

This process consists in winding spirally round a horse-shoe bar of iron ABC a copper wire covered with silk thread. A galvanic current is then made to pass through the bar ABC by two wires W, *w*, communicating with two wooden vessels D, E containing mercury. When the voltaic apparatus consists of a single element, viz., one plate of zinc placed in a copper vessel, and having an area of 5 square feet, the magnet, when armed, as shown at *mn*, may suspend by the hook H 100 kilogrammes (2 cwt.).

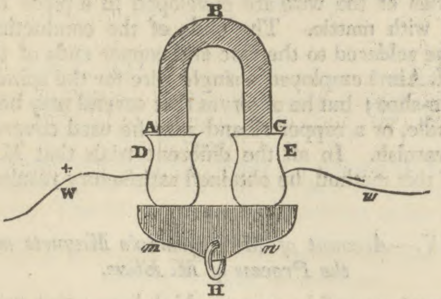

Fig. 85.

M. Moll[1] took a horse-shoe bar 0·22 of a metre high, and 0·025 thick, and rolled round it eighty-three times a copper wire covered with silk, and 0·003 of a metre in diameter. To each of the branches was adapted a counterweight of a pound weight, and projecting a little on both sides. The two extremities of the wire were made to communicate by small vessels of wood filled with mercury, with two elements of a voltaic battery, composed of a bucket of copper, in which was plunged a plate of zinc, whose surface, in contact with the fluid, was 11 square feet. The moment the communication was made, the magnet supported 25 kilogrammes, and with some precautions 38. Another horse-shoe bar, weighing 13 kilogrammes, 0·93 of a metre high, and 55 millimetres thick, lifted 77 kilogrammes. When the direction of the current is changed, the poles of the magnet are instantly reversed; and when the current is stopped, the magnetism of the bar diminishes, though M. Moll found it capable of carrying 25 kilogrammes a quarter of an hour after the current ceased. He found also that the magnetic intensity of the bar was not increased by increasing the number of the voltaic elements or plates; that a horse-shoe of copper was not magnetized; and that a horse-shoe magnet was not rendered more magnetic by the electric current.

Professor Henry.

Professor Henry of Albany Academy had obtained analogous results about the same time with Professor Moll. The apparatus which he used is shown in the annexed figure, which represents a strong rectangular wooden frame 3 feet 9 inches high and 20 inches wide. The magnet A is covered with linen, and the ends of the wires coiled round it all project so as to be soldered to the galvanic element B, which can be plunged into the vessel C, placed on a moveable shelf, and containing dilute acid. D is a graduated lever, E a counterpoise, and F a scale for supporting weights, when the lifting power is not estimated by a small weight sliding upon the lever. The magnet A was fitted up in the following manner:—"A bar of soft iron 2 inches square and 20 inches long was bent into the form of a horse-shoe 9½ inches high; the sharp edges of the bar were first a little rounded with a hammer; it weighed 21 lb. A piece of iron from the same bar, weighing 7 lb., was filed perfectly flat on one surface, for an armature or lifter; the extremities of the legs of the horse-shoe were also truly ground to the surface of the armature. Around this horse-shoe 540 feet of copper bell-wire were wound, in nine coils of 60 feet each. These coils were not continued around the whole length of the bar, but each strand of wire, according to the principle before mentioned, occupied about 2 inches, and was coiled several times backward and forward over itself; the several ends of the wires were left projecting, and all numbered, so that the first and the last end of each strand might be readily distinguished. In this manner was formed an experimental magnet on a large scale, with which several combinations of wire could be made by merely uniting the different projecting ends. Thus, if the second end of the first wire be soldered to the first end of the second wire, and so on through all the series, the whole will form a continued coil of one long wire. By soldering different ends, the whole may be formed into a double coil of half the length, or into a triple coil of one-third the length," &c.[2]

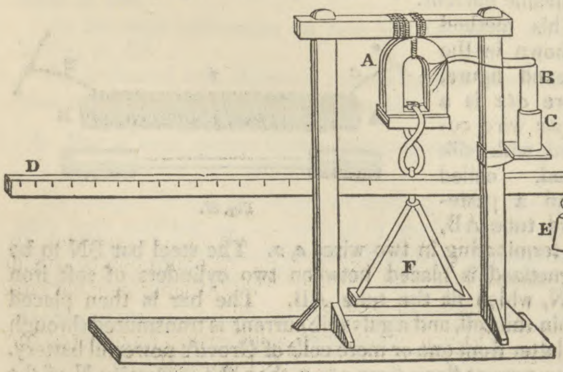

Fig. 86.

Methods of making Artificial Magnets.

In making experiments with this magnet, a small single battery was used, consisting of two concentric copper cylinders, with zinc between them; the whole of the zinc surface in action, including both sides of the zinc, was $\frac{2}{5}$ths of a square foot, and the quantity of dilute acid only half a pint. The following were the results:—

Number of wires soldered to the Battery in succession.		Weight lifted, in pounds avoirdupois.
1.	Each soldered to the battery in succession.....	7
2.	One on each side of the arch..........................	145
2.	One from each end of legs..........................	200
3.	One from each end of legs, and the other from middle of arch..........................	300
4.	Two from each end....................................	507
6.	Wires attached..	570
9.	All the wires attached................................	650
9.	A plate of zinc 12 inches long and 6 wide, and surrounded with copper, substituted for the preceding battery.........................	750

When a pair of plates, exactly *one inch square*, was attached to the wires, the weight lifted was 85 lb.

Professor Henry mentions that this magnet weighed 21 lb., and lifted more than 35 times its own weight; whereas the largest natural magnet known, and in the possession of Mr Peale of Philadelphia, lifts 310 lb., or about six times its own weight.

MM. Lipkens and Quetelet.

MM. Lipkens and Quetelet found that great effects will be produced by small voltaic surfaces, provided that the chemical action is energetic, and that the degree of magnetism depends more on the size of the iron shoes, than on the dimensions of the voltaic plates.[3]

Mr Watkins.

The horse-shoe iron magnets formed by electrical currents are only temporary, and it became interesting to discover the time of duration of the magnetism. Mr Francis Watkins made some interesting experiments on this sub-

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[1] *Ann. de Chim.*, vol. l., p. 326.

[2] Professor Silliman's *Journal*, 1831, vol. xix., p. 404.

[3] *Ann. de Chim.*, vol. l., p. 328-331; and Quetelet's *Corresp. Astronom. de Bruxelles.*

Methods of making Artificial Magnets.

ject.[1] He found that when the *armature* or *keeper* is *removed* from the two poles of the magnet, it instantly loses all its magnetism when the electric current is cut off; but that if the *armature* is kept upon the poles, the soft-iron magnet will retain its magnetism for a great length of time. Mr Watkins made a horse-shoe bar with a piece of soft iron 18 inches in length and 1 inch in diameter, and he rendered it magnetic by winding round it in a single helix 20 feet of copper wire $\frac{1}{16}$th of an inch thick. The ends of the copper helix being connected with a single pair of voltaic plates, the horse-shoe, when rendered magnetic by the current, supported 125 lb. The voltaic action continuing, the weight was reduced to 56 lb., and the voltaic plates removed; the weight was also carefully removed, so as not to displace the armature or keeper. The sustaining power of the horse-shoe was then tried every day, and at the end of ten days it sustained 56 lb. as firmly as it did at first. Another horse-shoe bar charged with magnetism in November, was as powerful, and rather more so, in April, than it was at first. After a lapse of fifteen weeks it frequently supported 30 lb. This soft-iron magnet was tried at the Duke of Sussex's house on the 27th of April, *and though nearly six months had elapsed since it received the magnetic virtue, it supported* 100 lb.; but the instant that the *keeper* was separated from the poles, almost all the magnetism disappeared. When the keeper was again applied, there was not enough of magnetism even to support the keeper.

Mr Watkins made some interesting experiments on the lifting powers of soft-iron magnets when plates of mica of different thickness were interposed between the poles and the keeper. The magnet was of the size and shape already stated; but Mr Watkins has not mentioned the successive thicknesses of the mica plates, nor does he state that they were of equal thickness. Had he mentioned the tints which each of them polarized, it would have been easy to compute their exact thicknesses. The following were his results:—

Number of Plates of Mica interposed.	Number of Pounds supported besides the Keeper.
1	49
2	40
3	26
4	17
5	13
6	8
7	4½
8	2½
9	2
10	1½
11	1
12	0¾
13	0½
14	The keeper only.
15	0

When a piece of common *writing-paper* was placed between the poles and the keeper, 28 lb. were supported by the magnet. Hence a piece of writing-paper was equal to *three* plates of mica.

SECT. XIV.—*Account of M. Aimé's method of making Permanent Artificial Magnets.*

Aimé's method.

A method of inducing magnetism, published by M. Aimé,[2] is one equally simple and efficacious. It is founded on the facts described in the preceding section, and consists in holding a bar of red-hot steel with pincers between the two poles N, S of a horse-shoe magnet rendered magnetic by an electrical current. The horse-shoe and the included bar, which should exactly fit the space between the poles, are then plunged in cold water, and kept there for a little time, depending on the size of the real magnet, till the bar is thoroughly cold along its axis. In order to prevent the brass spiral wire that is curled round the horse-shoe bar from being wetted when the apparatus is under water, the extremities of the wire are enveloped in a piece of linen covered with mastic. The ends of the conducting wire should be soldered to the zinc and copper ends of the battery. M. Aimé employed a single wire for the spiral round the horse-shoe; but he observes that several may be united in a bundle, or a copper riband may be used covered with silk or varnish. In all the different trials that M. Aimé made of this method, he obtained satisfactory results.

Methods of making Artificial Magnets.

SECT. XV.—*Account of M. Logeman's Magnets made by the Process of M. Elias.*

Logeman's magnets.

The most powerful magnets which have come under our notice are those of M. Logeman, optician, Haarlem, made by the process of M. Elias of the same town, who, like M. Aimé, availed himself of the magnetism produced by electrical currents. In the Great Exhibition of 1851, M. Logeman exhibited three magnets, which weighed respectively 43·6, 2·75, and 0·475 kilogrammes, or nearly 96, 5·75, and 1 lb. English. These magnets supported the following weights:—

Weight of Magnet.	Force of Magnet or weight supported.
96 lb.	232 lb.
5¾ „	45½ „
1 „	29 „

According to M. Haecker,[3] who made numerous experiments with various magnets, their force is proportional to the cube root of the square of their weight; and that if W is the weight of a magnet, and F its force, or the weight which it will support, then

$$F = 10{\cdot}23\ W^{\frac{2}{3}}$$

will represent the force of the best magnets made in Europe. It is obvious, however, from the above table, that the force of M. Logeman's magnets is nearly double of that given by the formula of Haecker. The following are the weights, forces, and prices of other magnets made by M. Logeman:—

Weight.	Force.	Price.
1 lb.	29 lb.	—
12½ „	150 „	L.8
52 „	430 „	20

The process of M. Elias by which these magnets were made, consists in making the magnet, with its armature attached, pass through a copper wire helix traversed by a galvanic current.

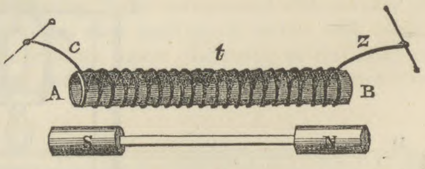

Fig. 87.

This method is shown in the annexed figure, where *ctz* is a copper wire covered with silk thread, coiled round a pasteboard tube AB, and terminating in two wires *c*, *z*. The steel bar SN to be magnetized is placed between two cylinders of soft iron S, N, which fit the tube AB. The bar is then placed within the coil, and a galvanic current is transmitted through the latter from one or more cells of Grove's powerful battery. If the current flows from *c* to *z*, then the extremity N of the bar will be a north pole.

M. Logeman has also applied the process of Elias in the construction of compass-needles, one of which was exhibited in 1851. In consequence of their greater magnetic power, these needles have a greater directive power, are less affected by the motions of the ship, and are useful in high latitudes where the ordinary compasses are of no service.

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[1] *Phil. Trans.*, 1833, part ii., p. 333-343.

[2] *Ann. de Chimie*, vol. lvii., p. 442.

[3] Poggendorff's *Annalen*, tom. lvii., p. 535.

Sect. XVI.—*Account of the Experiments made by Coulomb and Kater, on the efficacy of the different methods of making Artificial Magnets.*

Coulomb's comparison of different methods.

Coulomb was the first person who examined experimentally the value of the different methods of making artificial magnets. The following is a brief abstract of his results:—

1. *Wires of tempered steel twelve inches long and one-twentieth of an inch in diameter.*

When rubbed at right angles on the pole of a single artificial magnet, it performed 10 oscillations in 74^s.

When rubbed at right angles upon the poles of 4 united bar-magnets, or magnetized by the methods of Duhamel and Æpinus, it performed the same number of oscillations in the same time. Hence *small* steel wires attain their maximum degree of magnetism equally well by all the different methods.

2. *A plate of annealed steel twelve inches long, one-third wide, and one forty-second of an inch thick.*

When rubbed at right angles on a single pole, it performed 10 oscillations in 77^s.

When rubbed on *two* united poles, 10 oscillations in 75^s.

When rubbed on *ten* poles, 10 oscillations in 75^s.

By the methods of Duhamel and Æpinus, 10 oscillations in 75^s.

The effect of the different methods is now perceptible, the first being the worst.

3. *A plate of steel six and a half inches long, nine twenty-fifths wide, and one forty-second thick.*

When rubbed on 2 poles, 10 oscillations in 51^s.

Upon 5 poles, 10 oscillations in 49^s.

Upon 8 and 10 poles, 10 oscillations in $47\frac{1}{2}^s$.

By Duhamel's and Æpinus's methods, 10 oscillations in $47\frac{1}{2}^s$.

4. *A plate eight inches long, fourteen twenty-fifths wide, and one twenty-fifth thick.*

When rubbed upon *one* pole, 10 oscillations in 73^s.

Upon *four* poles, 10 oscillations in 62^s.

Upon *ten* poles, 10 oscillations in 59^s.

At an inclination of 15° or 20°, on *two* poles, 10 oscillations in 53^s.

At the same inclination on *four* and *ten* poles, 10 oscillations in 49^s.

By Duhamel and Æpinus's methods, with *one* or more bars on each side, 10 oscillations in 49^s.

5. *Bar of steel sixteen inches long, six-tenths wide, and one-fifth thick.*

By magnetizing it on Æpinus's method, with *two* moveable bars rubbing on its surface, it performed 10 oscillations in 110^s, and was found to be saturated. By Duhamel's method it required moveable bundles of 4 bars each.

6. *Bar of steel sixteen inches long, one inch broad, and nine twenty-fifths thick.*

When magnetized by Æpinus's method, with bundles of 4 or even 10 bars, it performed 10 oscillations in 153^s.

But by Duhamel's method, with even *ten* bars, it only performed 10 oscillations in 162^s.

Hence the magnetic force communicated by the first method was to that of the second as 9 to 8.

Directive force of needles.

Captain Kater made a series of interesting experiments on the directive force of needles, produced by different methods of magnetizing them. The needles which he used were right-angled parallelograms, 5 inches long, the one $\frac{7}{10}$ths of an inch broad, and the other $\frac{7}{20}$ths. The broadest was made thinner till it had the same weight as the other, which was 142 grains. The following table contains the result of the experiments:—

	Directive Force.	
	Small Needle.	Large Needle.
1. The magnets placed perpendicularly on the centre of the needle, and the needle rubbed from end to end on both sides	655	674
2. The same, but the magnets separated at top in the same way as at bottom	595	580
3. The same as No. 1, but the distance of the lower end of the magnets 2½ inches	760	780
4. The magnets joined on the centre of the needle, and each moved towards the nearest pole, then lifted up and joined again, and so on	993	1155
5. The magnets being joined on the centre of the needle, their lower ends were made to move to each pole, their upper ends remaining in contact	1025	1150
6. By Duhamel's method, the magnets inclined 45° to the needle, and moved from the centre to the poles	1070	1170
7. The same, but the inclination of the magnets 20°	1085	1195
8. The same, but the inclination only 2° or 3°	1160	1275
9. Magnets laid flat on the needle, and drawn from the centre to the end	1158	1261
10. Same as No. 8, but the separated ends of the magnets connected by an iron wire	1145	1261
11. Wire removed, and experiment No. 8 repeated	1260	1273
12. Needles hardened at a bright red, and then softened from the centre to within $\frac{3}{4}$ths of an inch of their extremities, and magnetized as No. 8	1815	1665

Captain Kater next ascertained the effect of length on the directive power of needles. He cut two needles of equal weight out of the same plate of steel, the one being 5, and the other 8 inches long.

13. Magnetized to saturation as in No. 8	1893	2275
14. Hardened and tempered beyond the blue, from the middle to within an inch of the poles	1865	2277

Hence it follows, as Coulomb had ascertained, that the directive force of needles whose length exceeds 5 inches is probably as their lengths.[1]

CHAP. XI.—DESCRIPTION OF MAGNETICAL INSTRUMENTS.

Magnetical instruments.

The great importance and value of magnetical instruments, not only in the arts of navigation and surveying, but in the determination of the various and ever-changing phenomena of terrestrial magnetism, renders it necessary that we should enter with some detail into this branch of the subject. As a magnetic needle constitutes the principal, if not the essential part, of the greater number of magnetical instruments, we shall begin our observations with some details respecting the forms, description of steel, temper, and construction of magnetic needles.

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[1] *Phil. Trans.*, 1821, p. 104.

Description of Magnetical Instruments.

SECT. I.—*On the best Form and Construction of Compass Needles.*

The most valuable experiments on this subject are those made by M. Coulomb and Captain Kater. Those of Captain Kater are particularly important.

Form, &c., of compass needles.

With regard to the material out of which the needle should be formed, Captain Kater found that needles of *shear steel* received a greater magnetic force than those of *blister steel*, or *spur steel*, those of *cast iron* being much inferior to the others.

Coulomb's experiments.

The next object of inquiry was to ascertain the form of the needle which is best suited for receiving the greatest directive power. The forms which have been generally used are, the cylindric, the prismatic, that of a rhomb or a parallelogram, and that of a flat bar which tapers to its extremities like an arrow. According to the experiments of Coulomb, the form last mentioned, "*une lame taillée en flèche,*" was the best, and was susceptible of a greater directive power than those which had the form of a parallelogram. He found that any expansion of the needles towards these poles was accompanied with a loss of power; and he drew the general conclusion, that in needles of the same form, their directive forces are proportional to their masses. Captain Kater likewise found that the directive force was little, if at all, influenced by the extent of its surface; but that it depended almost wholly on the mass of the needle when it was saturated with magnetism.

Captain Kater's experiments.

Captain Kater compared needles that had the form of a wide and a narrow rectangular parallelogram, and a small rhombus, a large rhombus, and a pierced rhombus, and he found that the form of the pierced rhombus is decidedly the best. A needle of this form (the sides of the rhombus are a little rounded in the figure), as made by Dollond, is shown in fig. 88, the cross piece at the centre being made of brass or copper.

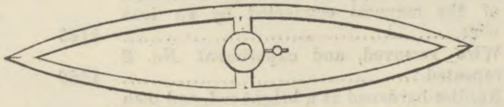

Fig. 88.

With regard to the best mode of hardening and tempering needles, Captain Kater found, that when a needle is considerably hardened throughout, its capacity for magnetism is diminished. He found that the needle was susceptible of the greatest directive power when it was first hardened uniformly at a red heat, and then softened from the middle to within an inch of its extremities, by using a degree of heat which is just capable of making the blue colour, which is thus produced, to disappear. Captain Kater likewise found that the polishing of the needle, previous to its being touched, had no advantage; and that an increase of pressure of the touching magnets on the needle was sometimes injurious, and never useful.

When the needle is magnetized, it has a cap *cc* fitted into the opening in its centre, seen in fig. 89, and about ¼th of an inch in diameter. This hollow cap is executed with great care, and is generally made of agate (garnet is much better). The interior curved surface, particularly the summit of it, requires the best workmanship. This summit rests on the pivot *n*, the point of which is wrought to an angle of from about 15° to 20°.[1] The use of the ring *aa* is to raise up the cap of the needle, and take it from the pivot when it is not in use. The rod or handle *r* of this ring is continued to the outside of the compass-box, where it can be put in motion, so as to disengage the needle from its pivot, or replace it at pleasure.

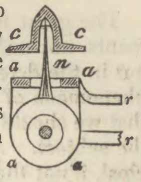

Fig. 89.

When a compass-needle is nicely balanced on a pivot, previous to its being magnetized, so as to traverse freely in a horizontal plane, it will no longer do so after it has been rendered magnetic. One of its ends will preponderate, in consequence of the tendency of the needle to dip, or place itself in a position parallel to the magnetic axis of the globe. In order to restore its equilibrium, therefore, it is necessary to add a small weight to one side of the needle, as shown in fig. 88. The weight requisite for this purpose will increase with the dip, so that it may be necessary to slide the weight farther from the centre in going towards the magnetic poles, and *vice versa*.

As the needle of ordinary compasses is generally placed upon a card on which the various points of the compass are marked, in stormy weather it is necessary to give weight to the card, to preserve it steady during irregular motions of the vessel. Various contrivances have been adopted to remedy this evil. The usual method is to load the card with sealing-wax. Some place pieces of paper, like vanes, on the lower side of the card, to act against the air, and check the vibrations; while others have proposed to make the needle move in oil or other liquid, with the same view. The consequence of these contrivances is, that while the weight of the card, or its resistance to motion, is increased, the directive power of the needle remains the same, so that in getting rid of one evil, another of greater magnitude is created. The mobility of the needle is diminished, and the steersman may mistake his course by trusting to the apparent steadiness of his compass. The simplest remedy for this evil is to use a heavier needle, with a greater directive power, or by combining several needles together.

Professor Barlow's card.

The latter idea was proposed by Professor Barlow, who constructed the card as shown in the annexed figure, where NESW is the card, and NS, N′S′, N″S″, *ns*, *n′s′*, five parallel needles placed at equal distances. Professor Barlow showed that the directive force of this combination of needles is nearly *four* times greater than that of a single needle; but as the weight and friction on the pivot is increased nearly in the same proportion, no other advantage is gained but the proposed one (particularly requisite in boat compasses) of making the cards steady by their additional weight, while the relative directive power remains the same.

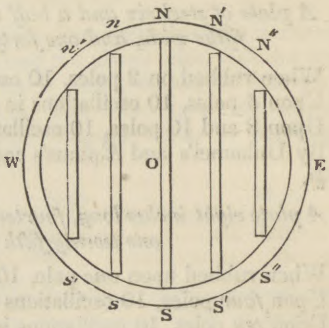

Fig. 90.

SECT. II.—*Description of the Common and Azimuth Compass.*

Compasses.

The common compass, whether it is called the *mariner's compass* or the *land compass*, serves only to point out the direction of the magnetic meridian, while *azimuth* compasses enable us to determine the angular distances of objects from the magnetic meridian.

Common.

The common compass consists of a needle fixed to a circular card, containing upon its surface the thirty-two points of the compass. This card is balanced, as already described, upon a pivot fixed in the bottom of a circular box, and the top of the box is a plate of glass for protecting the needle from motions of the air. This compass-box,

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[1] Coulomb, *Mém. de l'Institut.*, tom. iii., has shown that this is the best angle for pivots.

Description of Magnetical Instruments.

shown at AB, fig. 91, is suspended within a larger box PQ, upon two concentric brass circles or gimbals, the outer circles being fixed by horizontal pivots both to the inner circle, which carries the compass-box, and likewise to the outer box, the two axes upon which the gimbals move being at right angles to each other. The effect of this construction is, that the compass-box AB will retain a horizontal position during the motions of the vessel.

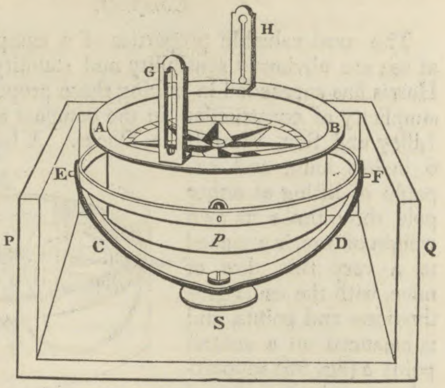

Fig. 91.

Azimuth compass.

The azimuth compass, shown in fig. 91, differs from the common compass principally in its being furnished with sights G, H, through which any object may be seen, and its angle with the magnetic meridian increased. For this purpose the whole box is hung in detached gimbals CD, EF, which turn upon a stout vertical pin, seen above S. In some instruments, the sights G, H may be turned down by a joint over the glass when the compass is not in use, as shown in fig. 92; and in others they are connected by a brass bar, and may be taken from the compass when they are not wanted. In this compass, the card is divided on its rim into 360°; but the divisions are more frequently placed on a light metallic rim which it carries. The eye is applied to the sight H, which is a slip of brass containing a narrow slit. The other sight G, which is turned towards the object, contains an oblong aperture, along the axis or middle of which is stretched a fine horse hair or wire, which is made to coincide with or pass over the object or point whose angular distance or *azimuth* from the magnetic meridian is to be determined.

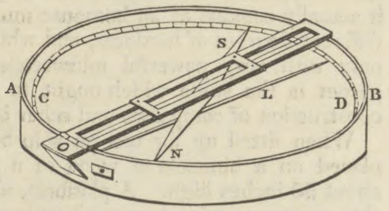

Fig. 92.

It is extremely difficult, when the ship is in motion, for the same person to take the bearing of the object and read off the angle; and various contrivances have been adopted to remedy this great defect. One of these is to have on one side of the compass-box a nut, which, when pressed by the finger, pushes a lever against the card, and stops its motion, so as to allow the angle to be read off at leisure; but a false reading is often obtained with this contrivance.

SECT. III.—*Account of Captain Kater's Azimuth Compass.*

Kater's azimuth compass.

This ingenious compass may be regarded as a universal instrument capable of being advantageously used both at sea and on land. It is represented in detail in figures 92, 93, and 94. In fig. 93, AB is a cylindric box made of brass, one inch deep, and covered with glass, and contains a card CD, 5 inches in diameter. The needle NS has an agate cap set in brass, and fixed in its centre. The needle is fixed to a circular piece of talc, on the circumference of which is laid a narrow ring of card, which is graduated to half degrees on its outer margin. On the inner side of the box there is fixed a standing piece of ivory, which just projects over the outer margin of the graduated circumference of the card, and an index-line is engraved on the ivory as a point of departure for reading off the divisions on the card. A brass sight-frame GH is fixed by a hinge at H, on the opposite side of the box. It has the form of a parallelogram, and is 5 inches long. A frame EF, 2 inches long, slides up and down upon GH, and contains the segment of a glass cylinder, whose radius is 5 inches. When the solar rays fall upon this cylindrical bar, they are collected into foci which form a line of light which is thrown upon the index-line of the piece of ivory, and which may be seen at the same time as the divisions on the card. The frame GH, when folded down, as shown in fig. 92, acts upon a lever L, which raises the needle NS, and prevents it from traversing by pressing it against the glass cover.

Description of Magnetical Instruments.

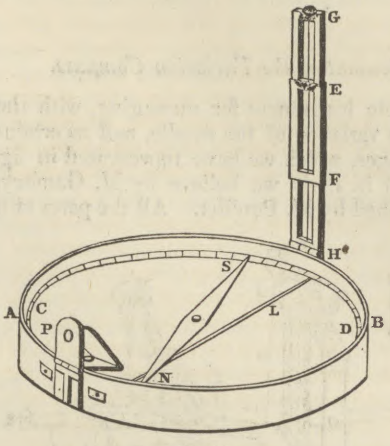

Fig. 93.

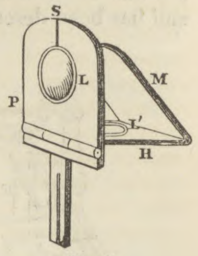

Fig. 94.

The sight-hole to which the eye applies itself is shown at P, figs. 93 and 94. It is an inch from its hinge to its summit, but may be raised higher by means of grooves, in which a branch below the joint covers it, as seen in the figure. The upright plane P has a slit S terminating below in a circular aperture, which receives a convex lens. To this is fixed a horizontal plane H, having a lens in its centre; and above this, inclined to it at an angle of 45°, is placed a mirror M, by means of which and the lenses, an eye looking through the lens below S sees magnified the divisions on the card, distinct vision being produced by sliding the sight upwards or downwards.

In order to take the sun's azimuth, raise the object-sight GH, and slide the cylindrical lens EF till its luminous line or focus falls upon the index. The eye-glass sight P is then to be moved up and down till it gives distinct vision of the index-line on the ivory. If the line of light is not narrow and well defined, incline the sight GH towards the compass till it is so, care being taken that the sight is perpendicular to the horizon, between the observer and the sun. When this is effected, incline the compass to the observer, so as to check the oscillations of the card by bringing it in contact with the index and two pins fixed near it for the purpose. When the card is made steady by the repetition of this, taking care that the compass is inclined as much from the observer as will just free the card from the index, and that the line of light is bisected by the index-line, this lens will indicate on the card the azimuth of the sun required, which, when the correction on the card is applied to it, will give the true azimuth of the sun from the magnetic meridian; and by means of this element and the observed altitude, the variation of the needle may be obtained in the usual way.

In using this compass for surveying, the cylindrical lens is slid to the top EG, and the hair or wire GH is then seen; and when this hair is made to bisect any object seen by direct vision, we have only to read off the azimuth of that object as seen on the card viewed by reflection.

Description of Magnetical Instruments.

By turning back the reflecting sight P round its hinge, the line of light may be viewed on the index, and the angle read off by direct vision, a mode of observation which has its advantages.

SECT. IV.—*Account of the Variation Compass.*

Variation compass.

The very complete instrument for measuring, with the nicest accuracy, the variation of the needle, and ascertaining its diurnal changes, which we have represented in fig. 95, was constructed in Paris, we believe by M. Gambey, and has been described by M. Pouillet. All the parts of it which are of metal are executed in copper. A table NN of white marble supports the pillars and case of the instrument. The columns C, D, are those by which the needle is suspended, and E, F, G, H, those which support the microscopes M, M′. The box of the needle is shown at BB′, and the needle itself AA′ is placed in the small copper ring *op*, to which is fastened a wire or a number of silk threads without torsion, which suspend the needle, and which may be rolled round the small cylinder seen between *c* and *d*, and turned round by the milled head *e*. This wire is kept in the centre of the little graduated circle *cd*, by crossing at that centre a small triangular aperture. The wire is inclosed in a small cage of glass, which rises between the two columns C, D, in order that the air may neither be agitated nor penetrate into the box. By turning the milled head *e*, the needle AA′ may be raised or depressed at pleasure. Two moveable panes of glass shut up the apertures A, A′ of the box, which are above the two ends of the needle. Upon each of the extremities of the needle there is firmly fixed a small plate of ivory *mn*, *m′n′*, bearing a very minutely divided scale, each of the divisions having the angular value of 15′ or 20′.

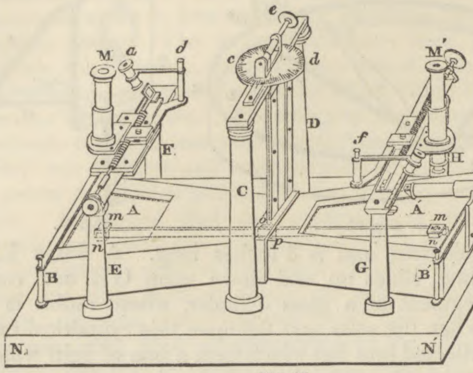

Fig. 95.

When the apparatus has been placed as nearly as possible in the plane of the magnetic meridian, and carefully levelled, we must see that the silk thread is without torsion; and by a few trials the microscopes M, M′ may be directed so as to see the zero or index of the ivory scales at the ends of the needle. It is then easy to observe the displacements which the needle experiences, either by counting the divisions which have passed under the wire of the microscope, or by following its motions by means of the screw by which the microscopes are moved. Small microscopes, one of which is shown at *a*, and moveable round the rods *b*, *f*, are used to read off the position and course of each microscope M, M′ along the bar which carries it, and which regulates its lateral motion.

The telescope T is used for counting more conveniently, and consequently more correctly, the oscillations of the needle, when we wish to employ it for measuring the magnetic intensity. It carries before its object-glass a mirror, which reflects the vertical rays along the axis of the telescope.

SECT. V.—*Description of Sir William Snow Harris's Compass.*

Harris's compass.

The most valuable properties of a compass to be used at sea are obviously sensibility and stability. Sir William Harris has succeeded in uniting these properties with great simplicity of construction, in the compass made by Messrs Lilley and Son, West India Docks. A bar-needle, about 6 inches long, and capable of lifting at either pole three times its own weight of iron, is attached to a very thin disc of mica, with the usual graduations and points, and is balanced on a central point *c* (fig. 96) supported by a double curved bar, *anb*, fixed to a dense ring of copper *acbd*, so that the poles almost touch the ring. This ring, as discovered by M. Arago, exercises such an electro-magnetic action upon the needle, that it soon brings it to rest when it has been made to vibrate by the motion of the ship or any other cause. In heavy seas the oscillation was found not to exceed from one-fourth to half a point each way, and in screw propellers the compass proved particularly steady. In some of these compasses, which are now extensively used, defects have been found from the abrasion of the agate centre, and in such cases the agates were found defective. The agate is certainly the worst of the hard minerals that are fitted for pivots of any kind, as it actually consists of an immense number of thin strata of different degrees of hardness, and which can often be seen only with very powerful microscopes. The Greenland garnet is the stone which ought to be employed in the construction of compasses and other instruments.

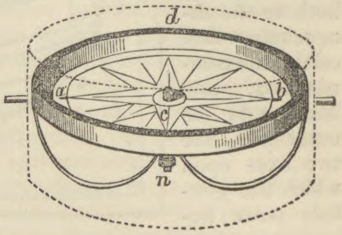

Fig. 96.

When fitted up for use on ship-board, this compass is placed on a binnacle of wood of a cylindrical form, and about 30 inches high. A platform, about 20 inches below the compass, carries two small spring candle lamps, which throw their light upon the transparent card, and illuminate it efficiently and economically at night.[1]

SECT. VI.—*Description of Mr Swan's Simple Variation Compass.*

Swan's variation compass.

A new variation compass was constructed in 1852 by Mr John Adie, Edinburgh, for the purpose of measuring the declination of the needle more accurately than by ordinary compasses. It consisted of a delicately suspended compass-needle, inclosed in a tube furnished with collars, which are placed in the Y's of a theodolite, after the telescope has been removed. The ends of the needle, being made sharp points, are brought nearly into contact with finely divided glass diaphragms, and by means of powerful eye-pieces, the place of the needle is determined. Being desirous of having a contrivance of the same kind applied to a Kater's altitude and azimuth circle which he possessed, Mr Swan was obliged to adopt an arrangement totally different from Mr Adie's, as the telescope of his circle did not admit of

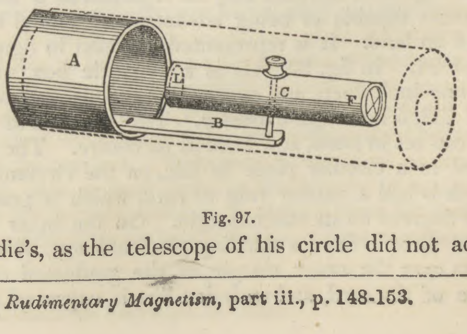

Fig. 97.

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[1] A fuller description of this compass will be found in Harris's *Rudimentary Magnetism*, part iii., p. 148-153.

Description of Magnetical Instruments.

being removed. In figure 97, A is a collar fitted to slide without much friction upon the object end of the telescope of the theodolite with which it is to be used, B an arm projecting in front of the telescope, and having a fine steel point C, and LF a small collimating magnet, having an agate cap, which moves upon the point C. The magnet should be a hollow cylinder, carrying at one end an achromatic lens L, and at the other a cross of spider lines F. These lines being in the focus of the lens L, will be seen distinctly by the telescope. The magnet is protected from currents of air by a light tube of copper or brass, shown by dotted lines, in the outer end of which is an aperture covered with glass, through which a small reflector throws light upon the cross wires. For further information consult Mr Swan's papers in the *Transactions of the Royal Scottish Society of Arts*, vol. iv.; also *Transactions of Royal Society of Edinburgh*, vol. xxi., part ii., *On Errors caused by Imperfect Inversion of the Magnet in Observations of Magnetic Declination.*

SECT. VII.—*Description of Colonel Beaufoy's Variation Transit.*

Beaufoy's variation transit.

This instrument, which was employed by Colonel Beaufoy in the valuable series of magnetic observations which he made between the years 1813 and 1821, is represented in perspective in fig. 98, where FF is a mahogany board, which forms the support of the instrument, resting on three screws G, H, I, by which it can be levelled. Above this is a flat plate of brass EE, fixed to the board by a centre pin, and resting upon three studs projecting from the board. It has a small horizontal motion round the centre pin, by means of the screw W and milled head X. The plate EE carries the graduated arc *m*, which is subdivided by the vernier D projecting from the box *ddd*, containing the needle AA. This box moves on the common centre pin of the plate EE. In the plate which carries the vernier D is fixed the frame *aab*, which is furnished with a clamp-screw L to fasten it to the arc *m*, and a tangent screw K, by which the box *ddd* can be moved round its centre pin.

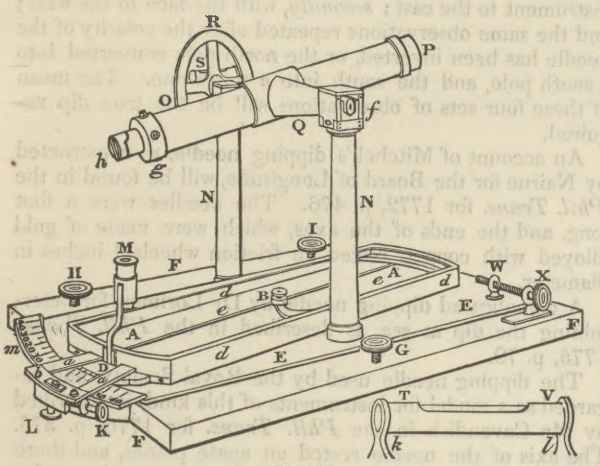

Fig. 98.

The centre pin of the box *dd*, and plate EE, terminates in a very fine pivot, on which the needle AA is suspended by means of an agate cap B, for diminishing the friction. The needle AA, which is a cylinder, is 10 inches long and $\frac{1}{500}$th of an inch in diameter. It weighs sixty-five grains, and is terminated by two conical points; and it is furnished with the usual lever, &c., for lifting it from the pivot of suspension and lowering it again. There are within the box *dd*, and beneath the ends A, A of the needle, two segments of brass, which have the centre lines drawn upon them; and these lines are brought to the points of the needle when the observation is made, by observing the coincidence through the double microscope M, which can be removed to the opposite end of the box.

Description of Magnetical Instruments.

The transit telescope OP rests on two pillars N, N, fixed on the brass plate EE, and having at their summits small boxes *f* for the reception of the Y's, in which the pivots of the conical axis Q of the telescope are supported. At the end of one of the pivots of this axis is fixed a small divided circle R, on an arm of which, provided with a level S, are placed the verniers for reading off the divisions. The eye-piece *h* admits a dark glass for solar observation, and the wires of the eye-piece are adjusted by screws at *g*. There is also a detached level TV, whose feet *k*, *l* are placed in different directions upon the plate EE, for the purpose of levelling it. The use of the telescope is for finding the true meridian by means of the sun or stars, and the meridian should be indicated by fixed meridian marks.

When the instrument is properly levelled, and the telescope placed in the true meridian, the needle is allowed to settle, and the box *dd* is turned upon its centre till its mark comes near the point A of the needle. The clamp-screw L is then fixed to the arc *m*, and the screw K is turned till the coincidence of the index with the point of the needle is seen through the microscope M to be perfect. The vernier D will then show the exact angle of variation, or the declination of the needle from the true meridian.

SECT. VIII.—*Account of Dollond's Variation Transit.*

Dollond's variation transit.

This instrument is shown in fig. 99. A brass pedestal CD, supported by three screws for adjusting it horizontally, forms the foundation of the four pillars which support the transit telescope AB, on the axis of which is fixed the graduated circle E, provided with all the usual contrivances for the accurate adjustment of the axis of the transit, and with microscopes for reading off the degrees. A cap or cover, seen separately at *a*, and containing a lens, is placed before the object-glass of the telescope, in order to convert it into a transit microscope; the focus of the lens being suited to the distance of the needle, seen between C and D, and the divisions of the graduated circle in the compass-box CD; the centre of the lens corresponding accurately with that of the object-glass. By this method the correct place of the divisions, as well as of the needle, may be readily ascertained, and the extreme deviation, as well as its diurnal changes, accurately determined. This instrument may also be used as a theodolite, and employed also for taking altitudes and equal altitudes.

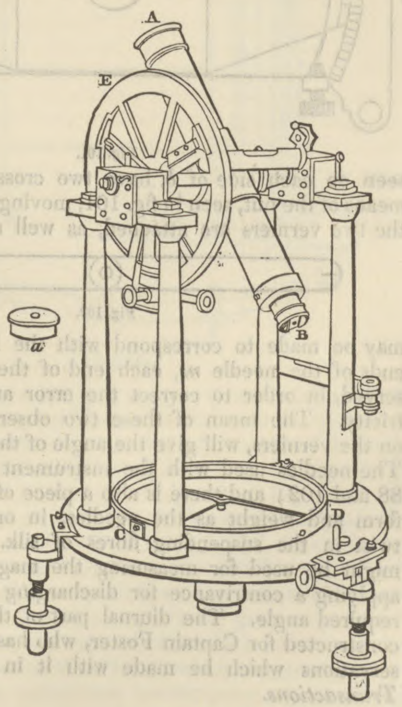

Fig. 99.

SECT. IX.—*Description of Dollond's Diurnal Variation Instrument.*

This instrument is shown in figs. 88, 100, 101, and 102.

Dollond's diurnal variation instrument.

It is made of mahogany and ivory, in order to avoid the attraction supposed to reside in all the metals. The needle *ns* is supported by the silk fibre *cbd* passing over a pulley at *b*, and counterpoised by a ball *d*. The two microscopes, seen on each side of *b*, have two cross wires, which, by means of the nut, seen in fig. 101, moving the frame to which the two verniers are attached, as well as the microscope, may be made to correspond with the index-lines on the ends of the needle *ns*, each end of the needle being observed, in order to correct the error arising from eccentricity. The mean of these two observations, as read off on the verniers, will give the angle of the diurnal variation. The needles used with the instrument are shown in figs. 88 and 102; and there is also a piece of brass, of the same form and weight as the needles, in order to detect any twist in the suspending fibres of silk. This instrument might be used for measuring the magnetic intensity, by applying a contrivance for discharging the needle at the required angle. The diurnal part of this instrument was constructed for Captain Foster, who has published the observations which he made with it in the *Philosophical Transactions.*

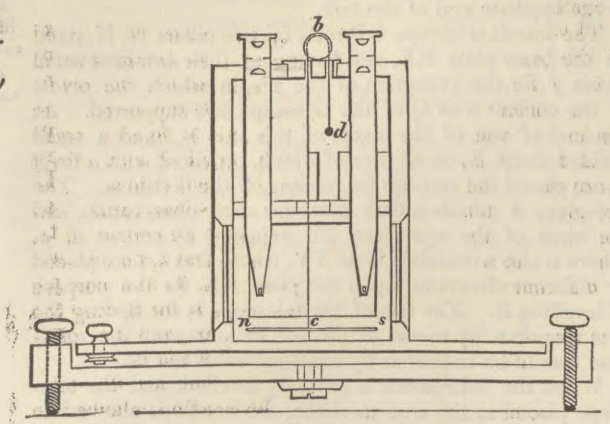

Fig. 100.

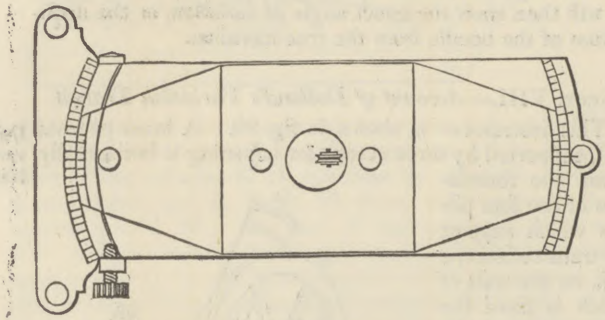

Fig. 101.

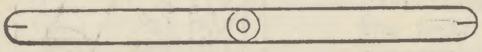

Fig. 102.

Sect. X.—*Description of the Dipping Needle as constructed by Messrs Gilbert.*

Gilbert's dipping needle.

After the dip of the needle was observed, and its changes discovered, instruments of various forms were contrived and used, under the name of *dipping needles*, for measuring the dip or inclination of the needle to the horizon. One of the most complete of these instruments, as constructed by Messrs W. & T. Gilbert, is shown in fig. 59, in perspective. It consists of a brass plate CAB, supported by three screws A, B, C upon a flat board or stand. In the centre of this brass plate is another ED, concentric with the former, and moveable round a centre pin like the moveable plate of a theodolite. This plate ED carries two levels at D for adjusting the plate horizontally. Four supports, shown at E and F, carry the circular box HGP, or principal case of the dipping needle NS. Two equal brass bars, one of which is seen at KL, are firmly fixed across the case in a horizontal direction. Other two brass pieces *m*, *n* are fixed by screws to the centre of the bars K, L, and carry two finely polished planes of agate, on which the axis of the needle NS rests, and upon which it turns freely. There is a contrivance inside the box G, and on the other side of KL, not seen in the figure, by which the observer, by turning the milled head P, can lift, by means of Y's, the needle from the agate planes, or lower it upon them, at pleasure; the Y's being carefully adjusted, so as always to leave the axis of the needle on the same part of the agate planes, and in the centre of the divided circle. In this instrument the ends N, S of the needle are graduated so as to act as a vernier scale for subdividing the degrees of the divided circle into 6′. A microscope is attached to the rim of the glass face, so as to be easily placed on any part of it, for the purpose of reading off the dip. In this instrument the length of the needle NS is six inches.

In order to obtain an accurate measure of the dip, several measures of it should be taken; *first*, with the face of the instrument to the east; *secondly*, with the face to the west; and the same observations repeated after the polarity of the needle has been inverted, or the north pole converted into a south pole, and the south into a north one. The mean of these four sets of observations will be the true dip required.

An account of Mitchell's dipping needle, as constructed by Nairne for the Board of Longitude, will be found in the *Phil. Trans.* for 1772, p. 476. The needles were a foot long, and the ends of the axes, which were made of gold alloyed with copper, rested on friction wheels 4 inches in diameter.

A complicated dipping needle by Dr Lorimer, for determining the dip at sea, is described in the *Phil. Trans.*, 1775, p. 79.

The dipping needle used by the Royal Society, and regarded as a model for instruments of this kind, is described by Mr Cavendish in the *Phil. Trans.* for 1776, p. 375. The axis of the needle rested on agate planes, and there was a contrivance, as in Gilbert's instrument above described, for raising and turning the needle upon the same part of the planes.

In one of M. Gambey's dipping needles, executed at Paris, and intended to be used at St Petersburg, the axis, instead of being cylindrical, is a knife edge, as in delicate balances. This edge is placed exactly in the centre of gravity of the whole compound needles, and is so fixed, that when the needle dips 71° (as at St Petersburg), the edge rests perpendicularly on two agate plates. Such dipping needles, made for particular values of the dip, are admirably fitted for measuring minute variations of inclination, whether they be diurnal, menstrual, or annual.

Sect. XI.—*Account of Dr Scoresby's Magnetometer for measuring the Dip of the Needle.*

Scoresby's magnetometer.

This ingenious instrument consists of a horizontal table, or leaf, a part of which, made of brass, may be set by a screw and pinion at any angle to the horizon; and this leaf contains near one of its edges two rings, through which we can pass a bar of soft unmagnetic iron, so that its length is perpendicular to the axis or line round which the brass leaf moves. On the same side of the leaf, and concentric with the above axis, is a graduated circle divided into 360°, so that when the bar of iron is put into the rings of the brass

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leaf, the bar coincides, in every position of the leaf, with a radius of the divided circle; and it is therefore easy to measure the angle which the bar makes with the horizon, whatever be the position of the leaf on which it rests. A compass is placed on the fixed leaf of the table, which by means of levels may be adjusted to a horizontal position.

Now it was ascertained by Mr Barlow, that when a bar of iron is in the magnetic equator, it loses all its power of affecting the needle of a compass placed near it. Dr Scoresby therefore elevates the brass leaf of the table, and consequently the bar of iron, till it ceases to act on the needle; and the complement of the inclination of the bar, as measured by the graduated circle, is the dip required. This method is of course not equal in accuracy to that described above, or to the methods of Mayer and Dr Lloyd, explained in subsequent sections. It may be used, however, most advantageously in obtaining an approximate measure of the dip when more delicate instruments cannot be procured. See the *Edinburgh Transactions*, vol. ix., p. 247; and the *Edinburgh Philosophical Journal*, vol. ix., p. 41.

SECT. XII.—*Description of Sir William Snow Harris's Hydrostatic Magnetometer.*

Snow Harris's hydrostatic magnetometers.

This ingenious instrument is of such universal application in exhibiting the elementary phenomena of magnetism, and in measuring magnetic forces, that an accurate description of it, both as an instrument of illustration and research, cannot fail to be acceptable to our readers. With the kind permission of its author, we have availed ourselves of the accurate description of it given in the 2d part of his *Rudimentary Magnetism.*

"A light grooved wheel, W (fig. 103), about 2 inches in diameter, being accurately poised on a firm axis *m n*, is mounted on the smooth circumferences of two similar wheels *mw, nw'*. The extremities of the axis *m n* are turned down to fine long pivots, and whilst resting on the friction-wheels *mw, nw'*, pass out at *mn*, between other small check-wheels, two at each extremity of the axis, so that the wheel W cannot fall to either side: great freedom of motion is thus obtained. These friction and check wheels are set on points or pivots in light frames of brass, and the whole is supported on short pillars screwed to a horizontal plate or stage AB (fig. 104). The stage is sustained on a vertical column AE, fixed to an elliptical base of mahogany E, supported on three levelling screws.

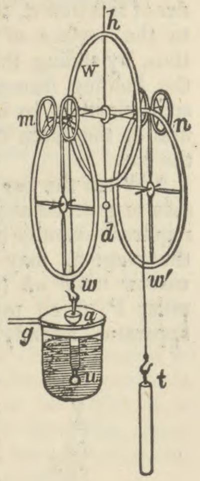

Fig. 103.

"There is a short pin *h*, fig. 103, fixed in the circumference of the wheel W, to receive an index of light reed, cut to a point, and moveable over a graduated arc MN, placed behind the wheel, as represented in fig. 104: the weight of this index is balanced by a small globular mass *d*, moveable on a screw in the opposite point of the circumference; so that the wheel alone with the index would rest in any position, or nearly so. The arc MN is a quadrant divided into 180 parts,—90 in the direction OM, and 90 in the direction ON, the centre O being marked zero. Two fine holes are drilled through the wheel, one on each side of the point *h*, for receiving and securing two silk lines, *w, w'*: these lines pass over the circumference on opposite arms of the wheel, and terminate in small hooks, *t* and *w*. A cylinder of soft iron *t*, or a small magnet, rather less than 2 inches in length and $\frac{1}{4}$th of an inch in diameter, is suspended by a silk loop from one of these lines *w*, and a cylindrical counterpoise of wood, *au*, weighted at *u*, and partly immersed in water, is hung in like manner from the other line, *w*. The weights, and altitude of the water, and of the vessel V containing it, are so adjusted, that when the whole system is in equilibrio, the index is at zero of the arc MN. With a view to a perfect adjustment of the index, the water-vessel V is supported in a ring of brass at the extremity of a rod *g*, moveable in a tube *k* (fig. 104): this tube is attached to a sliding piece *kh*, acted on by a milled head at *h* and a screw within the cylinder, which is fixed to the stage AB,—so that the water-vessel may be easily raised or depressed by a small quantity, and thus the index be regulated to zero of the arc with the greatest precision; for it is evident, by the construction of the instrument, that the position of the index will depend on the greater or less immersion of the cylindrical counterpoise *au*, the weight of which being once adjusted to a given line of immersion, and a given position of the wheel W and index O, any elevation or depression of the water-vessel V must necessarily move the wheel. The counterpoise *au* is about $1\frac{1}{2}$ inch in length and full ·3 of an inch in diameter: a small ball of lead is attached to its lowest part, in order to give it a sufficient immersion, and at the same time balance the iron cylinder *t* when the float is about half immersed in the water. With a view to a final regulation of the weight, a small hemispherical cup *a* is fixed on the head of the counterpoise for the reception of any further small weights required. This counterpoise is accurately turned out of fine-grained mahogany, and is freed from grease or varnish of

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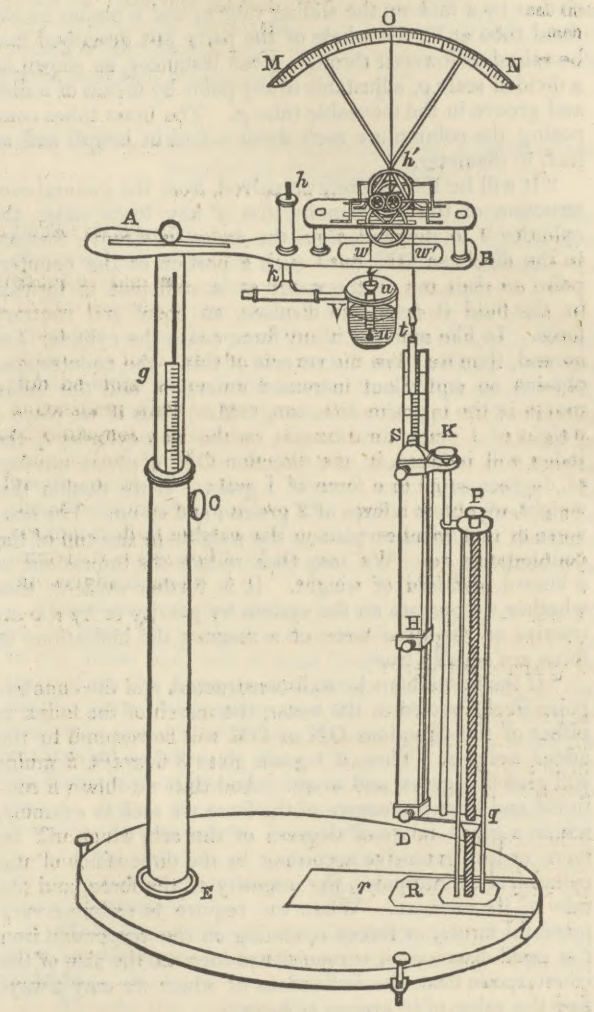

Fig. 104.

Description of Magnetical Instruments.

any kind, so as to admit of its becoming easily wetted in the water.

"The column AE supporting the stage AB consists of two tubes of brass, one *g* moveable within the other EC, so that by a rack on the sliding tube *g*, and a pinion on the fixed tube at C, the whole of the parts just described may be raised or lowered through given distances, as shown by a divided scale *g*, adjustable to any point by means of a slide and groove in the moveable tube *g*. The brass tubes composing the column are each about a foot in length and an inch in diameter.

"It will be immediately perceived, from the general construction of this instrument, that if any force cause the cylinder *t* to descend, then the index will move forward in the direction ON, until such a portion of the counterpoise *au* rises out of the water as is sufficient to furnish, in the fluid it ceases to displace, an equal and contrary force. In like manner, if any force cause the cylinder *t* to ascend, then we have the reverse of this,—the counterpoise obtains an equivalent increased emersion, and the index moves in the opposite direction, OM. Thus if we place a weight of 1 grain, for example, on the iron cylinder *t*, the index will indicate, in the direction ON, a given number of degrees equal to a force of 1 grain. If we double this weight, we obtain a force of 2 grains; and so on. The converse of this arises on placing the weights in the cup of the counterpoise *au*. We may thus reduce the indications to a known standard of weight. It is further evident, that whether we operate on the system by gravity or by the attractive or repulsive force of a magnet, the indications of force are equally true.

"If the instrument be well constructed, and the counterpoise freely wetted in the water, the march of the index in either of the directions ON or OM will correspond to the added weights. Thus, if 1 grain gives 3 degrees, 2 grains will give 6 degrees, and so on. And thus we obtain a continual and known measure of the force we seek to examine, within a given range of degrees of the arc, which will be more or less extensive according to the dimensions of the cylindrical counterpoise, the intensity of the force, and the rate of its increase. When we require to examine very powerful forces, or forces operating on the suspended iron *t* at small distances, it is requisite to increase the size of the counterpoise float, the indications of which we may always find the value of in grains, as before.

"Previously to suspending the cylindrical counterpoise *au*, the iron cylinder *t* should be placed in equilibrio on the wheel W, with an equal and opposite weight, as previously determined by an accurate scale-beam, in order to observe if, when loaded with the whole, the wheel W and index are indifferent as to position on any part of the arc, or nearly so. The instrument will be sufficiently delicate, if, when loaded in this way with 350 grains, it is set in motion by something more than half a grain added to either side.

"In order to retain the wheel W (figs. 103 and 104), in its position at the time of removing either of the suspended bodies, a small brass prong is inserted at h' into the arms of the circular segment MN, so as to inclose the pin h' carrying the index: the wheel is thus prevented from falling to either side.

"The forces requiring to be measured are brought to operate on the suspended cylinder *t* through the medium of induction on soft iron, or by a magnetic bar placed immediately under it, either vertically or horizontally. In the vertical arrangement, shown in fig. 104, the magnet or iron is fixed against a graduated scale S, by which the distance between the attracting surfaces or bodies is estimated. This scale, together with the magnet H, is secured by light bands of brass, united by a rod DK. The lower band and rod D are both fixed to a stage D, moveable between guide-pieces, and acted on through a nut at *q* by a vertical screw P*q*, about 6 inches in length and $\frac{3}{8}$ths of an inch in diameter; so that the whole may be raised or depressed, and hence the suspended cylinder and magnet placed at any required distance apart. The regulation of this important element in the operation of magnetic forces is hence provided for in two ways, viz., by the rack at *g* and the milled head at P, either of which may be employed, as found most convenient. The scale S is of boxwood, 1 foot in length, $\frac{3}{4}$ths of an inch wide, and $\frac{1}{4}$th of an inch thick: it is divided into inches, subdivided into tenths and twentieths of an inch. About 6 inches of the upper part is divided in this way, viz., 3 inches on each side of a central division, which is marked zero; the rest of the piece extends to the stage D. The magnetic bar H is tied to the scale by compressing screws and simple brass bands, either fixed, as at D and K, or moveable, as at H. This adjusting apparatus is secured to a stout brass plate R, fitted by a dovetail into a sliding piece *r*, forming part of the mahogany stand E, so that it may be removed at pleasure. The brass bands and frames at D, H, K, are sufficiently capacious to inclose two bars together if required, the superabundant space being filled when only one magnet is employed, either by a bar of wood or small wedge pieces in the brass frames.

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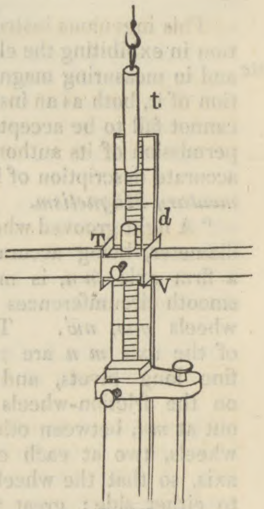

Fig. 105.

"When we require to examine the forces in different points of a moderate-sized magnetic bar, the bar is laid in a small frame-piece TV (fig. 105), temporarily fixed by a compressing screw to the divided scale S, in the way already described; the force on the suspended cylinder *t* being caused to operate through a small cylinder of soft iron *d*, accurately fitted to the surface of the bar; and thus, by sliding the bar along in the holding frame, we may get, approximately, by induction on the iron *d*, the force of any point in the bar.

"When the bar is of considerable magnitude and weight, or we require to examine inductive forces, the magnets may be placed on a narrow table *ab* (fig. 106), supported on a central square pillar P, fitted to the frame-pieces KP of the adjusting apparatus already described, so that the whole may be raised or depressed through any given distance. In this case the divided scale S (fig. 106), which measures the distance *a* between the attracting or repelling surfaces, is a detached piece fixed against one of the perpendicular sides of a right-angled triangle, so as to be anywhere placed upright on the bar: the table *ab* also has a divided scale *s*, moveable in a wide groove through its centre,

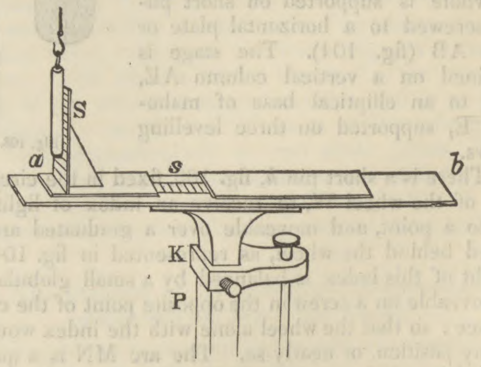

Fig. 106.

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by which any distance *s* between magnetic masses may be also shown. When the bars are very ponderous, two supports are required, one at each end of the table *ab*.

"Inductive forces are examined vertically by fixing the masses by compressing bands *s* against the scale S, as represented in the annexed fig. 107, and of which we may have, if requisite, two or three in succession.

"These arrangements put us in a position to note readily and simultaneously all relative distances and forces under a great variety of magnetic and apparently complicated conditions. In the arrangement (fig. 107), for example, we may fix a mass of iron S, at successive distances S, N from a magnet H, and yet preserve the distance *ab* at which the induced force operates constant, either by the rack and pinion C, or the milled head and screw PR (fig. 104), and thus arrive at a measure of the inductive force on the intermediate mass S."

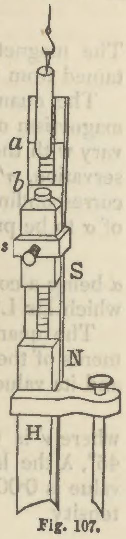

Fig. 107.

SECT. XIII.—*Account of Daniel Bernoulli's Dipping Needle.*

Bernoulli's dipping needle.

If AB is a needle, C its axis, a light graduated circle DEFG is fixed upon it, so as to have its centre coincident with C, and a light index D is fixed to the axis C, so as to turn tightly upon it. Let the needle be magnetized previous to the putting on of the index D, and nicely balanced. The index will obviously destroy the equilibrium, and will always point perpendicularly to the horizon, if the needle has been properly balanced. As this degree of accuracy, however, cannot be expected, let the index D be set to different parts of the circle EFG, and let the inclination taken by the needle before it is magnetized be noted down, corresponding to the different positions of the index. When the index points to 50°, for example, let the inclination of the needle be 46°. If we now observe that the needle is still inclined 46°, when the index is at 50°, after it is magnetized, then 46° is the true magnetic dip at that place, as the magnetism which it has received does not alter the position which it assumes from its gravity alone.

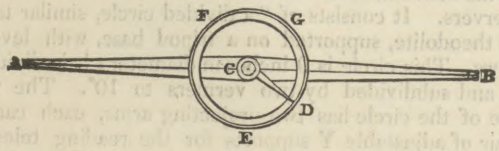

Fig. 108.

As it is easy to obtain a rude estimate of the dip at any place, let the index D be set accordingly, and if the needle does not now show the estimated dip, the position of the index must be changed, and the inclination or dip of the needle again noted. Observe if this second position of the index, and the second measure of the dip, form a corresponding pair of numbers, such as have been written down. If they do, we have got the true dip; but if they do not, another position of the index must be tried. If the coincidence of this new pair of numbers is greater or less than that of the former pair, we shall learn whether the position of the index is to be altered in the same direction as before, or in an opposite one.

Dr Robison made several observations with a dipping needle of this construction, which was executed by a person totally unacquainted with the making of such instruments. He measured the dip with it at Cronstadt, at New York, and Scarborough, and the result never deviated more than 1½° from that obtained by the present dipping needles. He tried it also in a rough sea in Leith Roads, and he found it not inferior either in accuracy or despatch to the most elaborate instruments.

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SECT. XIV.—*Account of Mayer's Dipping Needle, as constructed for General Sabine.*

Mayer's dipping needle.

The method of observing the dip employed by the celebrated Tobias Mayer,[1] consists in separating the centres of motion and of gravity of the needle, and in deducing the true dip from the apparent dip thus obtained.

The needle executed for General Sabine on this principle was a parallelopiped 11½ inches long, $\frac{4}{10}$ths broad, $\frac{1}{20}$th of an inch thick. The ends were rounded, and a line drawn on the face of the needle through its centre to its extremities, for the purpose of an index. The needle turned upon a cylindrical axis of bell-metal, terminated by cylinders of the smallest diameter, that could support the needle without bending. These small cylindrical ends rested upon agate planes. The needle was raised from or lowered to its support by Y's, which insured that the same parts of the small cylinders rested on the agate planes in each observation.

A small steel screw was inserted in a female screw, tapped on the lower edge of the needle, in a direction perpendicular to the index line, and a small brass sphere was made to traverse on this screw, so that the centre of gravity of the needle, screw, and sphere may be made to fall more or less below the axis of motion, and thus give the needle a momentum auxiliary to that of magnetism, in overcoming the inequalities of workmanship in the axis, or in the agate planes. Hence the position which the needle assumes, under these circumstances, is not that of the true dipping needle; but, by a simple formula, the true dip may be deduced from four observations, when conducted in the following manner:—

1. Place the needle in the magnetic meridian, and observe the angle which it makes with the vertical. Call this angle M.

2. Reverse the position of the axis on its supports, so that the edge of the needle, which was uppermost in the preceding observation, is now lowermost, and observe again the angle which the needle makes with the vertical, and call this *m*. Let the poles of the needle be now reversed by means of a powerful magnet, and when it is replaced, make the same observations which have been already described, and call the angles thus obtained N, *n*. Then calling the sum of the tangents of M and $m = \text{A}$; the difference of the same tangents $= a$; the sum of the tangents N, $n = \text{B}$, and their difference $= b$. Then the dip Δ may be obtained from the following formula:—

$$\text{cotan}\ \Delta = \tfrac{1}{2}\left(\frac{\text{A} \times b}{a + b} + \frac{a \times \text{B}}{a + b}\right).$$

In order to insure the perfect horizontality of the agate planes, or of the axis of the needle which rests upon them, a spirit level attached to a circular brass plate, with adjustments to bring the level parallel to the plate, was placed upon the planes themselves. The errors of the level were shown by placing the plate in various positions, and the errors of the planes by turning the whole instrument on its horizontal centre.

If we observe the inclination of the dipping needle to the horizon in two different positions, so that the planes in

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[1] *Göttingen Transactions*, 1814.

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which it moves are at right angles to one another, the true dip may be obtained from the formula:—

$$\text{cotang}^2 \Delta = \text{cotang}^2 \text{I} + \text{cotang}^2 \text{I}';$$

the inclination in the two rectangular azimuths being I and I′. The dip may be thus very accurately obtained from the mean of a number of observations in different azimuths.

SECT. XV.—*Account of Dr Lloyd's method of observing the Dip and the Magnetic Intensity at the same time, and with the same Instrument.*

Dr Lloyd's method of observing the dip, &c.

The ordinary dipping needle employed by Dr Lloyd, is supported on an axis which is supposed to pass accurately through its centre of gravity, and hence the position which it takes in the magnetic meridian is the direction of the magnetic force. If one of the arms of the needle, however, is loaded with a weight, the needle will assume a new position of equilibrium under the united influence of gravity and of terrestrial magnetism. By means of the inclination of the needle thus obtained, and the amount of the added weight, the dip of the needle, and the magnetic intensity, may be obtained by the following formulæ:—Let μ, ν be the statical moments of two small weights attached in succession to the southern arm of the needle at fixed distances from its centre, and let ζ be the inclination obtained with the weight μ, and θ that obtained with ν. Then

$$\mu \cos \zeta = \varphi \sigma \sin (\delta - \zeta),$$
$$\nu \cos \theta = \varphi \sigma \sin (\delta - \theta);$$

the dip being denoted by δ, and the magnetic intensity by φ, and σ being a constant depending on the distribution of magnetism in the needle itself. Hence from the inclinations ζ and θ observed in the usual manner, and the ratio of the moments μ and ν, the dip and the relative magnetic intensity will be obtained at the several places of observation.

The most advantageous way of applying the preceding method, Dr Lloyd considers to be this: He observes the position of the needle, *first*, when *unloaded*; and, *secondly*, when loaded with a weight sufficient to bring it into a position nearly perpendicular to the line of the dip.

Now if $\mu = 0$, we shall have $\zeta = \delta$, or the inclination first observed becomes equal to the dip, when there is no weight acting with or against the directive force. This condition, however, is never accurately fulfilled; for, from the imperfect coincidence of the centre of gravity of the needle with the axis, the weight of the needle itself is sufficient to deflect it from the true line of the dip. We must therefore regard ζ as the approximate value of the dip, and compute the correction for reducing it to its exact value.

For this purpose put $\rho = \frac{\mu}{\nu}$, and dividing the first of the above equations by the second we have

$$\rho \frac{\cos \zeta}{\cos \theta} = \frac{\sin (\delta - \zeta)}{\sin (\delta - \theta)}.$$

Then if we make $\delta = \zeta + \epsilon$, the second term of the preceding equation becomes $\frac{\sin \epsilon}{\sin \zeta - \theta}$ nearly, since ϵ is a very small quantity, and we have

$$\sin \epsilon = \rho \frac{\cos \zeta}{\cos \theta} \sin (\zeta - \theta).$$

Hence we may find the dip by means of these two equations, and we may deduce the correction for an imperfect balance of the needle from the two observed inclinations without reversing the poles of the needle, as in the method of Tobias Mayer.

The value of the coefficient ρ in the last equation is given in the following formula:—

$$\rho = \frac{\cos \theta \sin (\delta - \zeta)}{\cos \zeta \sin (\delta - \theta)}.$$

The magnetic intensity at different stations may be obtained from the dip by the second equation.

The quantity σ, being the statical amount of the free magnetism of the needle, or the *magnetic moment*, must vary with the temperature. If τ is the temperature of observation, τ' a certain standard temperature, and σ' the corresponding value of σ, then if we suppose the changes of σ to be proportioned to those of τ, we have

$$\sigma = \sigma' (\text{I} - a) (\tau - \tau');$$

a being a constant to be determined by observation, and which Dr Lloyd found to be 0·00016.

The quantity ν is the sum (or difference) of the moments of the weight of the needle and of the added weight, and its value is

$$\nu = \nu' (1 - e \cos 2\lambda)$$

where ν' is the value of ν corresponding to the latitude of 45°, λ the latitude of the place, and e a constant, whose value is 0·002588. Hence we obtain for the magnetic intensity

$$\varphi = \frac{\nu \cos \theta}{\sigma' \sin (\delta - \theta)} + \frac{1 - e \cos 2 \lambda}{1 - a (\tau - \tau')},$$

an expression peculiarly adapted for logarithmic computation. (See *Memoirs of the Royal Irish Academy* 1835.)

SECT. XVI.—*Description of Dr Lloyd's Theodolite Magnetometer.*

Dr Lloyd's theodolite magnetometer.

This instrument is intended for the use of travelling observers. It consists of "a divided circle, similar to that of a theodolite, supported on a tripod base, with levelling screws. This circle is 9 inches in diameter; it is divided to 10′, and subdivided by two verniers to 10″. The upper plate of the circle has two projecting arms, each carrying a pair of adjustable Y supports for the reading telescope, at a distance of 6 inches from the centre. The telescope rests in these supports on a transit axis, which is rendered horizontal by the help of a riding level. The aperture of the object glass is $\frac{8}{10}$ths of an inch; a glass scale, divided to the $\frac{1}{400}$th of an inch, is fixed in its focus; and the eye tube is made to move across the scale in a dovetail slide.

"The magnets are hollow cylinders, each furnished as a collimator with an achromatic lens, and a fine line cut on glass in its focus. There are four such magnets: two of them being $3\frac{2}{3}$d inches long and $\frac{1}{2}$ an inch in exterior diameter, and two 3 inches long and $\frac{3}{8}$ths of an inch in exterior diameter. The larger magnets are furnished with a Y stirrup, in which they may be inverted; the small magnets have the ordinary tubular stirrup, with a suspension pin and screw socket. A hollow brass cylinder, of the same dimensions as the larger magnets, and carrying a small hollow cylindrical magnet within, serves to determine the amount of torsion of the suspension thread; it is likewise fitted up as a collimator.

"There are two boxes, within which the magnets are to be suspended. That belonging to the smaller magnets is a rectangular box of copper, closed by mahogany sliding sides, and having a circular aperture at each end filled with parallel glass. It is $3\frac{1}{2}$ inches long, $1\frac{1}{2}$ inch wide, and 1 inch deep internally; and the thickness of the metal is $\frac{1}{4}$th of an inch, so that it may act powerfully as a damper. A suspension tube of glass, 8 inches long, is screwed into an aperture in the top of the box; and is furnished with a graduated torsion cap at top, and a sliding suspension-pin. This box is made to fit on the centre of the upper plate of the circle, and is capable of removal at pleasure. The box employed with the larger magnets is of wood, and of the same form as the copper box, but somewhat larger. It is detached from the instrument, but may rest on the same

Description of Magnetical Instruments.

stand. A small wooden piece with a mirror serves to illuminate the magnet collimator, either from above or from the side, according as the light of day, or that of a lamp or candle, is employed.

"The measuring rod employed in deflection experiments is a compound bar of gun-metal, formed of two bars, the lower of which has its surface horizontal, and the upper vertical. It is 3 feet in length, and is graduated on its vertical surface. It is placed upon the upper plate of the circle, beneath the box, and at right angles to its longer sides; and it is so fixed that it may be removed with ease, and replaced exactly in the same position. The support of the deflecting magnet slides upon the upper bar, and is furnished with a vernier, by means of which the distance of the two magnets may be determined with accuracy and ease."

SECT. XVII.—*Description of Dr Lloyd's Instrument for Measuring the Inclination and its Changes.*

Dr Lloyd's inclination instrument.

In 1842 Dr Lloyd communicated to the Royal Irish Academy an account of a "new magnetical instrument for the measurement of the inclination and its changes." In consequence of the sources of error inherent in every direct process of determining the third magnetic element, indirect methods of determining the inclination were proposed in Germany—one by Professors Gauss and Weber, and the other by Dr Sartorius von Walterhausen. Dr Lloyd's method bears a close analogy in principle to the former, but it differs from it both as to the means employed, and in the end in view,—his main object being to determine the inclination-changes.

"If a soft-iron bar, perfectly devoid of magnetic polarity, be held in a vertical position, it immediately becomes a temporary magnet under the inducing action of the earth's magnetic force, the lower extremity becoming a north pole, and the upper a south pole. Accordingly, if a freely-suspended horizontal magnet, whose dimensions are small in comparison with those of the bar, be situated near, in a plane passing through one of these poles, it will be deflected from the magnetic meridian. The deflecting force is the induced force of the bar, which may be regarded as proportional to the energy of the inducing cause, *i. e.*, to the *vertical component* of the earth's force; while the counteracting force is the *horizontal component* of the same force, acting directly on the magnet itself, to bring it back to the magnetic meridian. Thus the magnet will take up a position of equilibrium, under the action of these opposing forces; and this position will serve to determine the ratio which subsists between them. When the right line connecting the centre of the horizontal magnet and the acting pole of the bar, is perpendicular to the magnetic meridian, the tangent of the angle of deflection will measure the ratio of the two forces, and will therefore be proportional to the *tangent of the magnetic inclination*. Accordingly, by observing the changes of position of the horizontal magnet, so circumstanced, we can infer those of the inclination itself.

"But the iron bar may have (and generally will have) a certain portion of *permanent* magnetism, which will concur with the induced magnetism in producing the deflection; and it becomes necessary to institute the observations in such a manner, as to be able to eliminate the effects of this extraneous cause. For this purpose we have only to invert the bar, so that the acting pole, which was uppermost in one part of the observation, shall be lowermost in the other. The induced polarity will, under these circumstances, be opposite in the two cases; and the acting force will in one case be the *sum* of the *induced* and *permanent* forces, and in the other their *difference*. The following is the construction of the apparatus:—

Description of Magnetical Instruments.

"The magnet is cylindrical; its length is 3 inches, and diameter $\frac{1}{4}$th of an inch. A mirror is attached to the stirrup by which it is suspended, by means of which the varying position of the magnet may be observed with a telescope at a distance, after the method of Gauss. This mirror is of course vertical; and it has a motion round a vertical axis, by means of which it may be adjusted to any desired position of the observing telescope. The mirror is circular, and is $\frac{3}{4}$ths of an inch in diameter. The moveable part of the stirrup to which it is attached has the form of a cross; and it is rendered vertical by means of three screws, near the extremities of three of the arms of the cross, the heads of which project and hold it. The mirror is maintained in contact with these heads by springs at the backs.

"The box is octagonal; the interval between the opposite sides is 4 inches, and that between the top and bottom 2 inches. The top and bottom, and the connecting pillars, are formed of gun-metal; the eight sides are closed by moveable pieces, three of which are of glass, and the rest of ebony. To the top of the box is attached an upright tube of glass, 8 inches in length, which incloses the suspension thread. The suspension apparatus at the top of the tube is of the usual construction; the circular piece to which it is attached has a movement of rotation, and its outer surface is graduated to 5°, for the purpose of determining the effect of torsion of the suspension thread.

"The base of the instrument is a circle of gun-metal, 6 inches in diameter, graduated on the edge. The box is connected with this circle by a short conical stem, forming the axis of a second plate, which revolves upon the fixed one. This moveable plate carries two verniers, by which the angle of rotation may be read off to minutes. Two tubular arms, slightly inclined to one another, are attached to this plate; and their other extremities are connected by a cross-piece, which carries a short scale at a distance of 18 inches from the mirror. This part of the apparatus is employed in determining the total angles of deflection.

"The soft-iron bar is a cylinder, 12 inches long and $\frac{3}{4}$ths of an inch in diameter. One of its extremities is inclosed in a hollow cylinder of brass, connected with a horizontal pivot which revolves in a fixed socket. The axis of this pivot being in the line passing through the centre of the suspended magnet, and perpendicular to the magnetic meridian, it is obvious that the bar has a movement of rotation in the plane of the magnetic meridian itself. The distance of the axis of the bar from the centre of the magnet is about 5 inches; and it is so placed that the induced pole is in the direction of the axis of the pivot, and thus remains fixed during the movement of the bar.

"The changes of position of the suspended magnet are observed at a distance by means of a fixed telescope and scale. The scale, whose divisions are reflected by the mirror, is attached above the telescope to the support near the eye-end."

SECT. XVIII.—*Description of Mr Fox's Dipping Needle Deflector, for measuring the Variation and Dip of the Needle, and the Magnetic Intensity.*

Mr Fox's deflector.

This ingenious instrument, for ascertaining the variation, dip, and intensity of terrestrial magnetism, was pretty extensively used by Mr Fox in different parts of the United Kingdom. The results have been published both in a table and in a chart in an extract from the *Report of the Royal Cornwall Polytechnic Society* for 1835.

The deflector is shown in figs. 109 and 110, where A is a cylindrical box of brass fixed vertically in the stem B and horizontal plate C, all of which can be turned round on their common axis D, ground into the centre of a tripod,

Description of Magnetical Instruments.

two of whose legs are shown at E and F. The graduated circle in C is subdivided by a vernier and tangent screw G, levels being placed at right angles to each other for adjustment. The needle *ns*, with a small grooved wheel *a* fixed on its axis, is supported by the concentric disc *c*, and a bracket *e* attached to the disc, the axis of the needle moving in jewelled holes. The disc *c* is accurately fixed into the back of the box, and may be turned round with the bracket on its axis by means of knobs on its back, shown in fig. 110. By this contrivance the bracket may be moved round to any convenient position, so as not to interfere with the dip of the needle in any latitude.

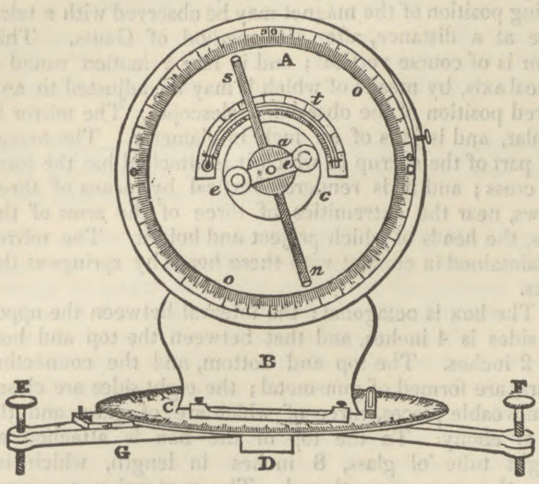

Fig. 109.

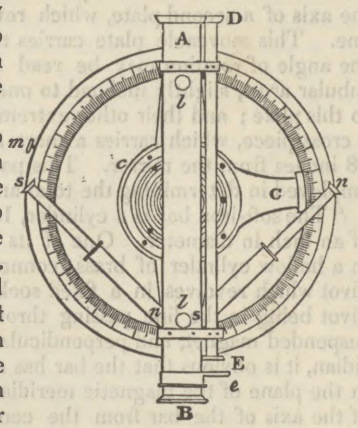

Fig. 110.

A socket, attached to a brass spring, when pressed forward by the screw *m*, is intended to confine the ends of the needle when not in use. There are two parallel graduated rings, one ot which is a little within the outer surface of the dipping needle, as shown at *oo* fig. 109; the other ring, supposed to be removed in the figure, is immediately under the glass, its object being to direct the sight, and enable the observer to subdivide the degrees on the inner circle. A thermometer is shown at *t*. The back of the dipping-needle box is shown in fig. 111; the back of the moveable central disc is grooved, and a brass rod is drawn over the grooved surface in order to make the needle vibrate.

A telescope AB, having cross wires, is capable of being moved in a vertical plane in any direction, by means of a concentric ring *c*, grooved into another concentric ring attached to the back of the instrument, and furnished with a flanch. An arm C, at right angles to the telescope, has a vernier for subdividing the graduated circle on the back of the box. A small tube DE for solar observations, is fixed parallel to the telescope. This tube has a convex glass at D, whose focal length is rather longer than the tube, and there is a plane glass at E, with a small circular spot on it, which forms, with the concentrated light of the magnifying glass, a distinct annular image on an ivory or plaster of Paris surface at *e*. Magnetized steel bars are placed in the brass tubes *ns*, *sn*. Their positition, as well as that of the telescope, when not in use, is shown in fig. 111, the *n* and *s* poles of the magnet being brought near the *s* and *n* poles of the dipping needle in the box, in order to induce a uniformity in their relative states of magnetic intensity. Holes *l*, *l* are made in the tube of the telescope, to allow the magnets to be passed through it, and screwed into the arms which hold the telescope. This is shown at *n* and *s* fig. 110, which represents a side view of the box, and the places of the magnet when employed for ascertaining the intensity. Two brass screws fix the ring and glass cover, over the face of the instrument, are shown at *a*, *a*. Fig. 112 represents a grooved wheel fixed in the axis of the needle *a* (fig. 109), with a fine silk thread, having hooks at each end, passing over the wheel in the grooves.

Description of Magnetical Instruments.

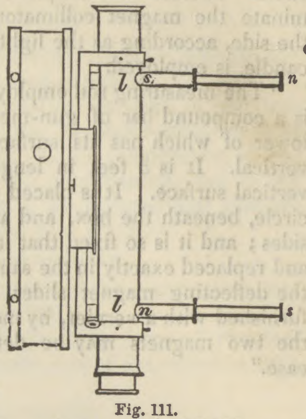

Fig. 111.

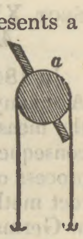

Fig. 112.

The following rules for using the instrument are given by Mr Fox:—

To observe the Magnetic Variation.—Ascertain the true meridian by any of the usual methods; the small tube being used for solar observations, and the telescope for observations at night. Note the angle cut by the nonius on the circular plate C. If the plate be turned round 90° from that point, the face of the instrument, or rather the plane in which the needle moves, being parallel to that of the tubes, will be at right angles to the plane of the true meridian. The deflecting tubes *n*, *s* having been removed from the back, turn the instrument round *gradually*, so that the needle may become *perfectly vertical* after vibration; friction having been employed several times at the back of the central disc. Fig. 110.

The face of the instrument will then be at right angles to the plane of the magnetic meridian; and the angle described on the circular plate will give the variation from the true meridian. The face of the instrument, however, should always be turned round to the opposite quarter, till the needle again becomes vertical, which will either confirm or correct the preceding experiment, by taking half the differenee between the two observations.

To ascertain the Dip.—The face of the instrument having been made to coincide with the *plane* of the magnetic meridian, suppose it to be at first turned towards the east; note the exact dip at *both* ends of the needle after vibration, as before described (this percaution should, in every case, be carefully attended to, and repeated several times); then turn the face of it toward the west, placing it in the same plane, and observe and note as before; the mean of these observations will give the dip.

To correct the observed Dip.—The instrument being still in the magnetic plane, and fixed in that position by means of the lever or clamp connected with the nonius, screw on one of the deflectors *n*, *s* at right angles to the tube as shown in fig. 111, so as to repel or deflect the end of the needle which is nearest to it; then, if the observed dip was 69° 45′, move the deflector a certain number of degrees from 69° 45′, as shown by the nonius *c*; say 50° to the right of the dip, when the needle will be repelled in the opposite direction: suppose the mean angle at *both* poles of the needle, after frequent vibrations, to be 54° 33′
then move the tube 50° to the left of the dip, when the needle will be repelled in the contrary direction: suppose it to stand at . . 84° 47′

Mean, . 69° 40′

Description of Magnetical Instruments.

If the face of the instrument, whilst making these observations, should be towards the east; turn it round towards the west, adjusting it in the same plane, and repeat the observation; if the mean result should be . . . 69° 46′
the mean or corrected dip will be . . . . 69° 43′

Similar observations may be multiplied at pleasure, by varying the angles of the deflector from the observed dip; and by thus taking the mean of many observations, the true dip may be obtained with a great degree of precision.

To find the relative Intensity of the Terrestrial Magnetism.—The instrument being still in the plane of the magnetic meridian, screw the deflectors (or one of them) into the arms at the back of the instrument, as shown in fig. 110, and cause the latter to coincide with the direction of the dip, when the needle will be repelled from it; mark the angle to which the needle points at both ends (after repeated vibrations as before described), then cause the needle to swing back to the other side of the dip (one of the deflectors being temporarily removed for this purpose), and note its place as before: half the sum of the angles to which the needle is thus deflected (or rather of their sines) will represent the relative force of the terrestrial magnetism, at different places, on a needle thus circumstanced. It is desirable that the observations should be made with the face of the instrument turned towards the east as well as towards the west, and likewise only one deflector may be used as well as both of them; in order to vary and multiply the observations for the purpose of correction.

If the angle of deflection at a second place of observation should be greater or less than at the first, the force of the earth's magnetism will be inferior or superior to the latter, as represented by the different angles

The amount of any such difference may, when required, be represented by weights:—For this purpose, the glass which protects the face of the instrument should be removed, and the silk thread placed on the grooved wheel, as shown in fig. 112. The minute weights required to be suspended to one of the hooks, in order to bring the needle to some given angle from the actual dip, will indicate the relative magnetic intensity at different stations. Suppose, for example, that at a given place the observed dip is 70°, and that at a second place, in a lower latitude, it is 45°; adjust the deflector as before described, so as to coincide with the dip of the needle at the place of observation, whatever it may be. Assume that the needle is repelled 70° from the dip of 70° at the first station, and 80° from the dip of 45° at the second station; it will show that the terrestrial magnetic intensity is greater at the former than at the latter. The weights required to be suspended to one of the hooks, in order to bring the needle to its original position of 71° from the dip (if that be taken as the standard), will indicate the difference of intensity. Thus, for instance, if five-tenths of a grain be required to bring the needle from the angular distance of 80° to that of 70° from the dip at the second station, this weight will indicate the *difference* of the magnetic intensity of the earth at the *two* stations, acting on the needle in question, when at an angle of 70° from the natural dip.

The ratio of this difference to the whole force of the terrestrial magnetism so acting, may be ascertained by moving the deflectors to the angle of 70° from the dip (because the needle is assumed to have been deflected to this angle at the first station); the needle will then be repelled to the opposite side of the dip, and the weight required to counteract the deflection sufficiently to bring it back to the dip, will represent the whole influence of the earth's magnetism, at the first station on the needle, whilst at the angle of 70° from the dip. This will be evident, when it is considered that the angle between the needle and deflectors is in both instances the same; it being coerced contrary to the repelling force of the deflectors, in one case by the earth's magnetism, and in the other by the weights, to the *dip or line of quiescence.* The earth's magnetic force acting on the needle so deflected, will therefore be equal to the gravity of the weights. If 3·34 grains be the weights required, and five-tenths of a grain equal to the difference between the two stations, the terrestrial magnetic intensity will be in the ratio of $3{\cdot}34 - {\cdot}5 = 2{\cdot}84$, at the second station, to 3·34 at the first station.

Description of Magnetical Instruments.

From the observations which have been already made with the dipping-needle deflector, furnished with a needle less than six inches long, there is good reason to believe that it will clearly indicate a difference of intensity at places situate at less than one-half a degree of latitude from each other.

Observations on the magnetic intensity and dip may likewise be made *without the deflectors*, by means of the weights only, suspended from the silk thread, shown in fig. 112. This method is too obvious to require a minute description, the weights in this case being used to produce deflection from the dip at any place, instead of the magnetic deflectors; the weights required to cause a given amount of deflection being taken as the relative measure of the magnetic intensity at the place of observation. Thus, in the case before supposed, 3·34 grains would produce a mean deflection of 70° from the dip at the first station, and only 2·84 grains would do so at the second station.

SECT. XIX.—*Account of Lebaillif's Sideroscope.*

Lebaillif's sideroscope.

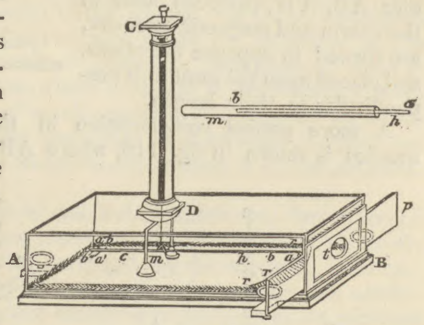

Fig. 113.

The object of this instrument, proposed by M. Lebaillif, is to detect minute degrees of magnetism by means of a very delicate combination of small magnetic needles. This apparatus, which he calls a *Sideroscope*, is shown in fig. 113, where ABCD represents the body of the instrument. The other parts consist of three sewing needles magnetized to saturation, and a tube of straw 12 or 15 inches long. One of these needles *ab*, is slid into the tube *mh*, and the others $a'b'$, $a''b''$, are placed across the straw, so that their dissimilar poles correspond. The straw thus fitted up is placed upon a small stirrup of paper, which is suspended by a silk fibre fixed at the top C of the vertical tube of glass or wood CD. The portion *mh* of the tube of straw is the longest, and it is beneath its extremity *a* that there is placed on the bottom of the cage or box AB, an arch *rrr*, divided into degrees and half degrees. The portion *mc* has no directive force, as the action of the earth is neutralized in the two opposed needles $a'b'$, $a''b''$. But the portion *mh* has a directive force depending on the magnetism of the needle *ab*, on its length, and on its distance from the point of suspension. The cage has a small sliding door *tp* which shuts up the apparatus; and when an experiment is made, the aperture at *t* is brought opposite the extremity *a* of the needle.

M. Lebaillif proved that almost all bodies exercise some action on the needle, and that *antimony* and *bismuth* always exert upon it a repulsive force. M. Pouillet, from whose work we have taken this description of the instrument, is of opinion that the movement of the needle may be often owing to atoms of iron; and that we must not take it for granted that in these phenomena the magnetic force is the only one which is acting.

SECT. XX.—*Description of the Astatic Needle.*

Astatic needle.

This instrument, described by M. Pouillet, is called the *Astatic Needle*, because it is withdrawn from the action of the earth's magnetism, and has no longer the statical position in which it is in equilibrio with the influence of this force. The construction of the astatic needle is founded on the principle that a body which is moveable round an axis cannot receive any motion from a force which acts parallel to this axis.

The astatic needle is represented in fig. 114, where *ns* is a magnetic needle, moveable round the axis *ab*. If this axis is placed in the direction in which terrestrial magnetism acts, the needle will rest in any position. This effect is easily produced by two motions perpendicular to each other, one of which is obtained by the milled head S, which, by an endless screw on its axis, works in the teeth of the wheel C, and the other by the milled head S′ and the wheel D; the graduated circle AB showing the positions of the needle.

Pouillet's astatic needles.

Another contrivance for an astatic needle is shown in the annexed figure (115), where two needles AB, A′B′, perfectly alike in their form and magnetic intensity, are turned in opposite directions, and placed upon the same axis perpendicular to their length.

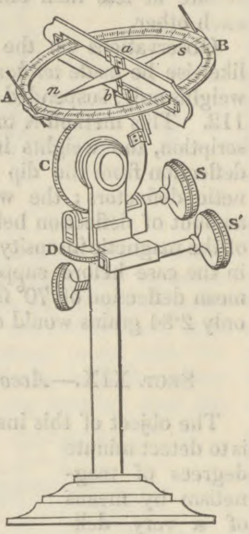

Fig. 114.

A more perfect compensation in the action of two needles is shown in fig. 116, where AB, AB are the two needles, the one horizontal and the other inclined to the horizon. It is obvious that the directive force of the latter will augment with its inclination, and it is therefore easy to make the directive forces of each perfectly equal and opposite, by varying the inclination of the uppermost one. These two contrivances we owe to M. Pouillet.

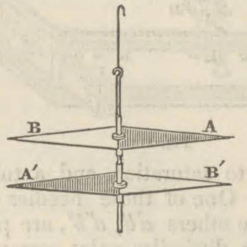

Fig. 115.

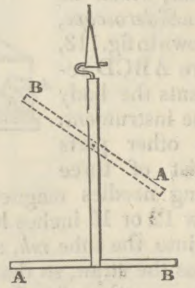

Fig. 116.

A magnetic needle may also be rendered astatic by neutralizing the action of the earth, by means of an equal and opposite magnetic action. For this purpose we have only to place a powerful bar-magnet at a considerable distance from the needle, so that it may act upon it as powerfully as the earth does. It should be placed in the magnetic meridian, parallel to the direction which the needle takes when it is in equilibrio, the pole of the bar which repels that of the needle being placed nearest it. When the bar is placed near the needle, it will cause it to wheel round, in consequence of its action exceeding that of the earth. At a very great distance, on the contrary, the earth's action will predominate, and draw the needle into the magnetic meridian; but an intermediate distance will be found in which the two actions exactly balance or compensate each other, and render the needle astatic.[1]

SECT. XXI.—*Account of Barlow's Correcting Plate or Magnetic Compensator for neutralizing the effect of local attraction on the Ship's Compass.*

Barlow's correcting plate.

As every ship contains large fixed masses of iron, beside moveable iron guns, anchors, cables, and iron utensils of various kinds, it is obvious, from the principles and experiments already detailed (see Chapter V., &c.), that these masses, rendered temporarily magnetic by the action of the earth, must produce derangements in the magnetic needles of the compasses on board. These derangements amount sometimes to 15° or 20°, and have exposed navigators to the most imminent perils. Mr Wales, the astronomer to Captain Cook's expedition of discovery, first discovered the fact that such a deviation existed, but he does not seem to have suspected its cause. Mr Downie, master of his Majesty's ship Glory, was the first person who pointed out the true origin of the deviation. "I am convinced," says he, "that the quantity and vicinity of iron in most ships have an effect in attracting the needle; for it is found by experience that the needle will not always point in the same direction, when placed in different parts of the ship. Also it is rarely found that two ships, steering in the same course by their respective compasses, will go exactly parallel to each other, yet these compasses, when compared on board the same ship, will agree exactly."[2]

In his survey of the coast of New Holland, in 1801 and 1802, Captain Flinders observed great differences in the direction of the needle, which arose only from changes in the direction of the ship's head, the direction being westerly when the ship's head was to the east, and *vice versa*. Hence he concludes, that the attractive powers of the different bodies in the ship which are capable of affecting the compass are collected into something like a focal point or centre of gravity, and that this point is nearly in the centre of the ship, where the shot are deposited, for here the greatest quantity of iron is collected together."[3] He likewise supposes that this magnetic centre is of the same name as the pole of the hemisphere where the ship is, and consequently, that in New South Wales the south end of the needle would be attracted by it, and the north end repelled; and from this hypothesis he concludes that the phenomena must be exactly the reverse in the northern hemisphere.

The Admiralty ordered a course of experiments to be made on this important subject; but though they established the truth of Captain Flinders' views, the subject was not farther prosecuted. The public attention, however, was again called to it by Mr Bain, who, in an excellent treatise on the variation of the compass, pointed out the fatal consequences which might result from this great source of uncertainty in the indications of the needle. The observations of Captains Ross, Parry, and Sabine threw additional light upon the subject; but it is to Professor Barlow alone that we owe a series of brilliant experiments, which terminated in his invention of the neutralizing plate, for correcting in a perfect manner this source of error in the compass.

In order to give an idea of the magnitude of this error, Professor Barlow published the following table of deviations actually observed:—

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[1] See Pouillet's *Elemens de Physique.*

[2] Walker *on Magnetism*, 1794, cited by Prof. Barlow.

[3] *Phil. Trans.*, 1805, p. 186.

Ship.	Place.	Observers.	Deviation in the compass.
Conway	Portsmouth	Captain Hill	4° 32′
Leven	North fleet	Captain Owen	6 7
Barracouta	Do.	Captain Cuttfield	14 30
Hecla	Do.	Captain Parry	7 27
Fury	Do.	Captain Hoppner	6 22
Griper	Nore	Captain Clavering	13 36
Adventurer	Plymouth	Captain King	7 48
Gloucester	Channel	Captain Stuart	9 30

The instrument employed by Professor Barlow is shown in figs. 117 and 118, where T is a rod of copper an inch and a half in diameter, and F, F′ two plates of iron about 12 or 13 inches in diameter, and of such a thickness that a square foot of it will weigh about 3 lb. avoirdupois. These plates are separated by a circular sheet of card, and pressed against each other at their centre by a screw on the end of the rod T, and at their margins by three small screws of iron. The compass C is placed on the top of a wooden box, and the corrector T is placed in one of the holes in the side of the box.

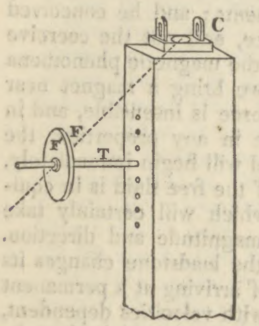

Fig. 117.

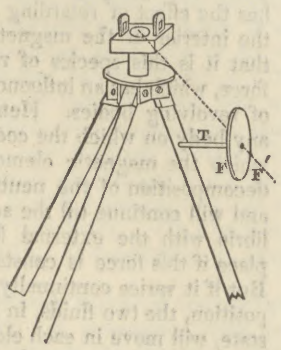

Fig. 118.

The adjustment of the plate is made when the ship is lying in a calm bay near the shore. An observer with a needle and theodolite is placed at some distance from the shore, from which he can perceive the ship while it is turning its head in different directions. The compass on board the ship is under the management of another observer with the same apparatus. At a signal given, the observer determines the angle which his own needle makes with the axis of the telescopes (one being directed to the other), which is called the central line. But as the needle on shore experiences no disturbing action, it is evident that if the needle on ship-board also experience none, the two needles will be parallel, and will form the same angle with the central line. Hence the difference between these two angles when they are not the same is that which is produced by the magnetic action of the iron in the vessel from its compass-needle at the instant of observation. Let the vessel be now made to turn round completely, and let a new observation be made at every azimuth of ten or twelve degrees, we shall then have the value of the deviation produced in all positions of the ship's head upon the compass-needle. When this is done, the observer on shore takes away his compass and replaces it with that of the ship, which he sets on the wooden cage shown in fig. 117, having different holes for receiving the axis T of the plates, F, F′. As the box is turned round its axis it carries along with it the compensator FF′, which will affect the needle of the compass C differently in different azimuths, and by a few trials it may be adjusted by means of the holes of its axis T to produce the very same deviation in the compass as was produced upon it when in the ship by the action of its iron. When it is done, the position of the centres of the plates F, F′, with regard to the needle is completely marked, and when it is taken on board the ship and placed in its proper position, the compensator is adjusted on the stand which carries the compass, as shown in fig. 118, so as to have exactly the same relative position as it had in the box.

Now since the compensator produces the same effect as the iron on ship-board does, the deviation will be *doubled* in place of being corrected; but this furnishes the means of making the correction. If the variation is found to be 36° W. by the compass *without the compensator*, and afterwards 40° with the compensator, the difference 40° − 36° = 4° shows that the compensator augments the variation 4°, and the iron on board the vessel as much. Hence the true variation will be 36° − 4 = 32°, or 40 − 4 − 4 = 32°. If the observations with the compensator had given a less result than without it, this would have shown that the action of the iron had diminished the declination, and the difference of the two observations must have been added to the first to have the true declination.

CHAP. XII.—THEORIES OF MAGNETISM.

Theories of magnetism.

The phenomena of magnetism, like those of every other branch of physics, have afforded the groundwork of many absurd and wild theories. The hypotheses of Descartes and Euler, which created in the interior of magnetic bodies canals and valves to admit or obstruct the subtle matter, to the agency of which they ascribed the attractive or directive power of magnets, are too ridiculous to deserve any notice in the present state of the science.

Theory of Æpinus.

M. Æpinus of St Petersburg was the first philosopher who discovered a rational hypothesis, which explained nearly all the phenomena of magnetism. This hypothesis of one fluid, however, of which we have already given a short account in our history of the science, was found insufficient for explaining the phenomena which are exhibited in the division and fracture of magnets; and although susceptible of a correction, which consisted in considering a magnet as composed of small particles of iron, each of which has individually the properties of a separate magnet, yet it did not afford a complete explanation of all the magnetic phenomena.

Theory of Wilcke, &c.

The hypothesis of two fluids, which was first proposed by Wilcke and Brugmann, was established by M. Coulomb, and was afterwards perfected by the masterly investigations of M. Poisson, who not only constructed mathematical formulæ which enable us to calculate all the minutest details of the phenomena, but has enabled us to comprehend physically how all the phenomena have been produced. The general equations at which he arrived have not yet, in every case, been resolved; but the particular conditions under which the integrations are possible have already, as we have stated, exhibited the most happy coincidence with experiment.

The hypothesis of two fluids supposes that they reside in each particle of iron; that they are neutral, and inert when combined as in soft iron; and that, when they are decomposed, the particles of the *austral* fluid attract those of the *boreal* fluid, and *vice versa*, while they each repel one another.

In order to account for the phenomena of the division and fracture of magnets, it is necessary to suppose, that when the united fluids are decomposed, the fluids undergo displacement only to an insensible distance. The minute portions of a magnetic body within which the motions and displacements resulting from decomposition take place, or in which magnetism exists, are called the *magnetic elements* of that body, and the small intermediate spaces where magnetism is not found, the *non-magnetic* elements. It is impossible to determine whether the *magnetic elements* are the intervals which separate the ultimate atoms of material bodies, or if they are the atoms themselves; nor can we ascertain whether they are the intervals between an aggregate number of atoms, or of a secondary molecule, or the aggregate members themselves. The theory regards the sum of the magnetic elements and of the non-magnetic elements as forming the apparent volume of a body. The ratio of these two sums may change with the nature and temperature of the body; and these changes exercise a powerful influence over the distribution and intensity of magnetism.

The quantity of each fluid in every magnetic element is unlimited in reference to our powers of separating them, as the united fluids can never be completely decomposed. The force which prevents this decomposition, and also the recombination of the fluids, is called the *coercive force*, and, like that of friction, it cannot be completely overcome. In soft iron this coercive force is extremely feeble. In the natural loadstone, and in steel, it is very powerful, varying in intensity in different kinds of this metal.

One of the most important consequences of the theory of Poisson is, that a magnetic needle whose size is so small that it exerts no sensible action on an iron sphere within which it is placed, will intercept the magnetic influence of the earth, and of all magnetic bodies without the sphere; and, in like manner, such a sphere will intercept the action of a magnet within it on all bodies without it. Another interesting consequence of the theory is, that in a hollow iron sphere, magnetized by the influence of the earth, or of any magnetic force the origin of which is at such a great distance that it may be considered as acting in parallel lines, although the magnetism is not confined to the surface of the sphere, and though its intensity may be determined for any particular point of the solid mass of the shell, yet it is determined only by the radius of the external surface, and the co-ordinates of the point upon which the forces act. When this point is very remote from the centre of the sphere compared with its diameter, each of the three forces is nearly in the direct ratio of the cube of the radius, and in the inverse ratio of the cube of the distance.

M. Poisson likewise applied his powerful mind to the explanation of the singular phenomena of magnetism produced by rotation. To the suppositions which his theory makes in order to explain the phenomena of magnetism induced by influence, he added another, namely, that all bodies exert upon the *boreal* and *austral* fluids a species of action analogous to the resistance of media, which action has the effect of retarding the motion of the two fluids in the interior of the magnetic elements; and he conceived that it is this species of resistance, and not the coercive force, which has an influence over the magnetic phenomena of revolving bodies. Hence, if we bring a magnet near any body on which the coercive force is insensible, and in which the magnetic elements are in any proportion, the decomposition of the neutral fluid will begin immediately, and will continue till the action of the free fluid is in equilibrio with the external force, which will certainly take place if this force is constant in magnitude and direction. But if it varies continually, or if the loadstone changes its position, the two fluids, in place of arriving at a permanent state, will move in each element with velocities dependent, other things being equal, on the resistance which the substance of the body opposes to them.

It is needless to enter into any further details respecting this very ingenious theory, as the later discoveries of Dr Faraday respecting electro-magnetic induction have enabled him to give a most satisfactory explanation of the diversified phenomena of magnetism in motion. (D. B.)

MAGNUS, ST, BAY OF, a large and beautiful bay on the W. coast of the mainland of Shetland, about 8 miles wide at its mouth, and afterwards expanding to about 11 miles, and extending 7 miles inland. It affords excellent anchorage for the largest vessels. The island of Papa-Stour is at the S. side of its mouth.

MAGONTIACUM, or MOGONTIACUM, shortened into Moguntia, a town of Gallia Belgica, now Mentz or Mayence, situated at the confluence of the Rhine and the Maine.

MAHABALIPURAM, a town of Hindustan, in Southern India, in the province of the Carnatic. It is noted for the celebrated ruins of ancient Hindu temples in the vicinity, dedicated to Vishnu, generally called the Seven Pagodas, though it is not known for what reason, as no such number exists here. There is a high rock, or rather a hill, of stone, about a 100 yards from the sea, covered with images, so thickly scattered as to convey the idea of a petrified town. On this hill a temple is cut out of the solid rock, with figures of idols carved in alto-relievo on the walls, and well finished. On an adjoining hill there is a gigantic statue of Vishnu asleep on a bed, with a huge snake wound round in many coils as a pillow; the whole cut out of one solid stone. A mile and a half to the southward of the hill are two pagodas, about 30 feet long by 20 wide. Near to these is the figure of an elephant as large as life, and of a lion much larger than life. There are here also other pagodas, and curious monuments of superstition. This town is said to have extended many miles to the eastward, into what is now covered by the sea; and there is every reason to believe that it was formerly a very large city. N. Lat. 12. 37., E. Long. 80. 15.

MAHABULESHWA, in Hindustan, a small town within the presidency of Bombay, situate on the summit of the range of mountains bearing the same name. In contrast with most other hill stations in India, this is totally free from malaria, and the place having, in many circumstances affecting health, a decided superiority over the more depressed and sultry tracts in its vicinity, was some time since selected as a sanatory station for troops; but after a short trial the project was abandoned, on the ground of the climate being unsuited to the acute diseases most common among the soldiers. It is, however, much frequented by invalid officers, for whose accommodation there is a sanatarium containing eight sets of quarters, and several detached bungalows. There are also about seventy private dwellings, many of them built of hewn stone. The number of visitors is steadily on the increase. The station was established in 1828 by Sir John Malcolm, the governor of Bombay. There is a small church, a subscription library, and a hotel; and the bazaar is well supplied. The elevation of the station above the sea is about 4500 feet. Lat. 17. 59., Long. 73. 41.

MAHANUDDY, a river of Hindustan, which has its source in Nowagudda, one of the petty native states, on the S.W. frontier of Bengal. It proceeds with a very winding direction towards the Bay of Bengal, receiving in its course the contributions of the Hutsoo and several other tributaries. Near the town of Cuttack it divaricates into the numerous branches inclosing or traversing the delta; the total length of its course being estimated at 520 miles. Its principal mouth is in Lat. 20. 20., Long. 86. 50.

MAHARAJPOOR, in Hindustan, a small town in the native state of Gwalior, or possessions of Scindia's family. This place was the key of the position of the Mahratta army on the 29th December 1843, when the battle took place between them and the British army under Sir Hugh Gough. The Mahrattas were driven from all points, lost 56 pieces of artillery, and retreated to the fort of Gwalior. The loss of the British was severe, amounting to 106 killed, 684 wounded, and 7 missing. No great disparity of numbers existed between the contending parties, the British having a force of 13,000, and the Mahrattas numbering about 15,000. A monument at Calcutta, constructed from the cannon captured on the field, commemorates the victory. Lat. 26. 29., Long. 78. 5.

MAHE, in Hindustan, a French settlement and seaport on the coast of Malabar, containing an area of 2 square miles. It is situate at a short distance from Tellicherry, on the banks of a river, which is navigable for large boats a considerable way up the country. Small vessels can also cross the bar, where there is a secure harbour. The town is neat, and contains many good houses. The principal export is pepper, which is produced in abundance in the surrounding country. It was taken possession of by the French in 1722, but was retaken by the British in 1761. It was restored at the peace of Paris in 1763, but was again taken in 1793. The British establishment, previously established at Tellicherry, was then removed to Mahe; but the place having been restored to the French at the general pacification of 1815, the British establishment was replaced in its original station at Tellicherry. The Carmelites have a church here. Pop. 2616. It is situate in E. Long. 75. 38. and N. Lat. 11. 42.

MAHIM, a town of Hindustan, is situate on the northern point of the island of Bombay. It possesses a small fort, originally intended for the defence of the channel running between it and Salsette. The town of Mahim stands at the point where the island of Bombay is connected with that of Salsette by a road running partly on arches of masonry, and partly on a causeway constructed by the government, aided by a munificent contribution from Sir Jamsetjee Jejeebhoy, a Parsee merchant of great wealth residing at Bombay. Here is the tomb of a Mohammedan saint, with a mosque attached to it; also a Portuguese church, with a college for Roman Catholic priests depending on it. It is 7 miles N. of Bombay fort. E. Long. 72. 54., N. Lat. 19. 1.

MAHMUD I., *Sultan of Turkey*, the son of Mustapha II., was born at Constantinople in 1696, and succeeded his uncle Ahmed III. on the Ottoman throne in 1730. He prosecuted the war which had been begun in the former reign against Nadir Shah of Persia. In 1734 the Russians commenced hostilities against the sultan, and in 1737 captured Oczakow and Kilburn. The Austrians joined them; but, after invading Wallachia, they were defeated at Krotska, and forced to accede to a disadvantageous peace in 1739. Not so honourable was the treaty struck soon afterwards between the Ottomans and Russians, by which the latter were allowed to retain part of the possessions they had captured. Meanwhile, a peace had been concluded with Persia in 1736, but was broken in 1743, and restored soon afterwards on terms unfavourable to the Ottomans. Mahmud died in December 1754.

MAHMUD II., *Sultan of Turkey*, the younger son of Abdul-Hamed, was born at Constantinople on the 2d September 1789, or, according to another account, on the 20th July 1785. He passed his early years in the Seraglio, engaged in the study of Turkish and Persian literature until 1808, when his brother Mustapha IV. was deposed and imprisoned, and himself raised to the throne, by Mustapha Baïraktar, pasha of Rusjuk. No sooner had he taken the sceptre than he appointed Baïraktar grand vizier, and boldly proclaimed his intention of prosecuting the reforms for which his uncle Selim III. had been deprived of his crown. He also restored the Nizam Jedid, or army organized according to European discipline. Startled at these proceedings, the Janissaries rushed to arms, besieged the grand vizier in his palace, and clamoured for the head of the sultan. At this crisis, Mahmud ordered Mustapha IV. and his infant son to be strangled, and his four pregnant sultanas to be sewn up in sacks and thrown into the Bosphorus. By thus becoming the sole male descendant of Osman, he rendered his person sacred in the eyes of his subjects, and was enabled more effectually to quiet the tumult. Then began his unsuccessful war with Russia, which was terminated by the peace of Bucharest on the 28th May 1812. Mahmud had for some time looked with a jealous eye upon the growing dominion of Ali, the ambitious pasha of Jenina, and he now strained all his energies to effect his overthrow. But no sooner had he succeeded in crushing him in 1822, than the Greeks broke out into open rebellion. Aided by the forces of Mehmed Ali, pasha of Egypt, the sultan suppressed this revolt with such sanguinary cruelty that Britain, France, and Russia interfered; and when their interference had been slighted, their combined armaments attacked and routed the Turko-Egyptian fleet in the Bay of Navarino in 1827. Meanwhile, at Constantinople, a desperate rebellion of the Janissaries, in 1826, had ended in the complete subjugation and dispersion of that order, and in the permanent establishment of an army organized according to the European system. Expecting that his soldiers, under their new discipline, would now be able to cope successfully with the armies of Europe, Mahmud declared war against Nicholas of Russia in 1828. After his forces had been cut to pieces, and General Diebitsch had occupied Adrianople, and Prussia, Britain, and France had interfered to effect a reconciliation, he unwillingly signed the treaty of Adrianople in 1829. With a determination untamed by so many reverses, the sultan now began to muster all his strength for the purpose of curbing the restless ambition of Mehmed Ali. The refusal of that pasha in 1832 to withdraw his troops from Syria, which his son Ibrahim had conquered in the preceding year, furnished Mahmud with a pretext for war. Accordingly, he commenced hostilities, but, with his usual ill fortune, was defeated by Ibrahim at Hems and Kouiah, and was only saved from total humiliation by the intervention of a Russian army. The result of this mediation was the treaty of Unkiar Skelesi, in which it was agreed that Russia should assist Turkey at any emergency with an armed force, and that Turkey in return should close the Dardanelles against all the foes of Russia. In 1834 another war between the sultan and Mehmed Ali was prevented by the interference of the European powers. In the midst of all these distractions from abroad, Mahmud had completed the reorganization of his army, had constructed roads, and had established postage communication throughout the country. Ambassadors were also stationed at Vienna, London, and Paris; and women, for the first time, were allowed to appear in public. Still intent, however, upon taking vengeance upon Mehmed Ali, he commenced hostilities in 1839, on the pretext of forcing that pasha to pay his arrears of tribute. His forces were defeated by Ibrahim near Nisibis; and he died on the 1st July 1839, before the news of the disaster reached Constantinople. He was succeeded by his eldest son, Abdul Mejid.

MAHOGANY, the timber of *Swietenia Mahogani* (Linnæus); Natural Order, *Cedrelaceæ*. The mahogany tree is a native of South America, Cuba, St Domingo, Jamaica, and especially of Honduras, and is one of the most magnificent and valuable of tropical timber trees. It grows rapidly, yet its timber is very hard and heavy; its height is from 80 to 100 feet, with usually a very straight stem of great diameter. It is commonly imported in logs from 2 to 3 feet square, of various lengths, not often exceeding 18 feet. That called Spanish mahogany is usually smaller, the logs being generally about 2 feet square by about 10 feet in length. The grain, or *curl*, as it is called, is sometimes so exceedingly beautiful that it raises the value of a log to an extraordinary price. More than L.1000 has been realized several times by the sale of a single log. Mahogany was introduced into England in 1595. By some the discovery of its value is attributed to the carpenter of Sir Walter Raleigh's ship; and another account states that it was first employed for cabinet-work in England in 1720, by one Wollaston, a cabinet-maker in London, who being accidentally requested to make some small articles from this wood for Dr Gibbons, a physician in that city, discovered its rare properties, which, on being made public, soon rendered both the workman and the material highly famous. It is chiefly imported from Honduras and Cuba. The average imports of the last five years are 38,000 tons, worth about L.500,000. (T. C. A.)

MAHOMET I., son of Bayazid I., was originally governor of the town and district of Amasia, and, after the death of his elder brothers, became Sultan of the Ottomans, A.D. 1413. He restored the Ottoman empire, extended his conquests into Bosnia, Servia, and Wallachia in Europe, and, after a reign of nine years, died A.D. 1421.

MAHOMET II., *Sultan of Turkey*, was born at Adrianople in 1430, and succeeded his father, Amurath II., in 1451. Bent upon overturning the Greek empire, he broke the truce that subsisted between the Turks and the Emperor Constantine, and in April 1453 beleaguered Constantinople with a large fleet and an army of 300,000 men. The Greeks, though only 10,000 strong, barricaded the mouth of their harbour with strong iron chains, and offered a determined resistance. The emperor himself was slain, fighting hand to hand with the besiegers. At last, however, by conveying a part of his fleet overland into the harbour, and by mounting a bridge of boats with cannon, Mahomet was able, after a siege of fifty-three days, to storm the city on the 29th May. Three days, devoted by his soldiers to massacre and pillage, rendered Constantinople desolate, and seemed to defeat Mahomet's design of making it his capital. Nevertheless, by granting to the Greeks religious toleration and the use of one-half of the churches that had survived the sack, he induced many of them to reinhabit the city. He also restored its fortifications, and erected at the mouth of the Hellespont the forts called the Dardanelles. In 1456 Mahomet, advancing westward, laid siege to Belgrade, but was defeated and forced to retreat by John Hunniades, general to Ladislaus, King of Hungary. More successful in his invasion of Greece, he subdued Corinth and the Morea. In 1461 he captured Trebisonde, and thus overthrew the dynasty of the Comneni. The islands of the Archipelago were added to his conquests in the following year. The Albanians, under their king Scanderbeg, had for some time successfully checked the advance of the Turks; but after the death of that prince in 1466, they too were subdued. From the republic of Venice Mahomet wrested Negropont in 1470. After taking the Crimea in 1475, he invaded Italy in 1480. No sooner, however, had he captured Otranto than he received the news that part of his forces had been foiled in their attempt to take Rhodes, by the knights who had fled thither after the sack of Constantinople. While he was preparing to retrieve that defeat he died in 1481. He was buried at Constantinople, and over his grave was written the following epitaph:—"I would have taken Rhodes and subdued Italy."

MAHOMET III. began his reign in 1595, as the successor of Mourad III., by putting to death all his brothers. He gave himself up to idleness and luxury, and before he could be roused from his sloth his troops were beaten in Hungary and elsewhere. He set out for that country with a large force, but after a few trifling successes, returned again to his capital, leaving his generals to prosecute the war. He died in 1603, while revolt raged in his Asiatic provinces, and mutiny in his capital.

MAHOMET IV., *Sultan of Turkey*, was born in 1642, and succeeded his father Ibrahim I. The chief exploits of his reign were those of the grand viziers Kuperli and his son Achmet. The Turks were defeated by the Hungarians at St Gothard, in 1664, by General Montecuccoli. The war with the Venetians, begun in 1645, was ended in 1669, when the town of Candia, after a siege of two years, capitulated to Achmet Kuperli. Encouraged by the internal discord of Poland under King Michael, the Turks successfully invaded that country in 1672; but in 1673 were routed by the famous John Sobieski, driven south of the Danube, and forced to sign a disadvantageous peace. In 1683 a horde of 200,000 men, under the grand vizier Kara Mustapha, marched westward, and encamped in front of Vienna. After a siege of six weeks, all hope of relief had been abandoned, when Sobieski, now King of Poland, attacked the Turkish forces, drove them from their entrenchments, and cut them to pieces. This was the first of a series of disasters that ended, in 1687, in an insurrection of the Janissaries, and in the deposition of Mahomet IV. He died in prison in 1691.

MAHOMETANISM. See MOHAMMEDANISM.

MAHRATTAS. The Mahratta state comprehended a country in Hindustan, very extensive, and of great natural strength, being interspersed with mountains, defiles, and fortresses, and well adapted for defensive war. It extended across the peninsula of India, and, generally speaking, was in possession of the peishwa, Nagpoor Rajah, Scindia, Holkar, Guicowar, and other inferior chiefs. The Mahrattas were not originally a military tribe, like the Rajpoots; nor do they possess the same grace and dignity of person, being of a diminutive stature and badly made, and having more the character of freebooters than of soldiers. Their original country is said to have included Khandesh Baglana and part of Berar, and to have extended N.W. as far as the Nerbuddah River. Others, again, say that they are foreigners who came into India from the western parts of Persia about 1200 years ago. Little is known of the history of the Mahratta people till about the middle of the seventeenth century, when they possessed a narrow tract of country on the western side of the peninsula, extending from N. Lat. 15. to 21. The founder of the Mahratta state, or at least the first person who raised this nation from obscurity, was Sevajee, who was born about the year 1626, and died in 1680, and who claimed a descent, but upon very doubtful grounds, from the ranahs of Odeypoor. The father of Sevajee, named Sahoo Bhosila, or Bhoonsla, was an officer in the service of the last Mohammedan king of Bejapoor or Visiapoor. The Mahratta country was originally divided amongst a number of principalities, ruled by independent chiefs, who at length acknowledged one leader, Sevajee. He was succeeded by his son Sambajee, who extended his conquests, but who was finally taken prisoner by Aurungzebe in 1689, and put to death. His son Saho, at the time of his father's death, was an infant and a captive. Saho was eventually liberated on the death of Aurungzebe, but found the succession contested by his cousin, as stated in the article COLAPOOR. His power was usurped by the two chief officers of the state, the peishwa or prime minister Balajee, and the paymaster-general Ragojee, who divided the empire between them. The former fixed his residence at Poonah; the latter founded a new kingdom at Nagpoor, in the province of Gundwaneh. Bajeerow, the second peishwa, died in 1759, and was succeeded by his son Ballajeerow. In 1760 the Mahrattas had extended their conquests as far as the city of Delhi, when a formidable rival appeared in Ahmed Shah Abdalli, the sovereign of Afghanistan, to dispute with them the empire of India. With the Afghans was fought, on the 7th of January 1761, the great battle of Paniput, in which the Mahrattas were speedily overthrown, with the loss of a great number of their chiefs. From this period their power began to decline. Ballajeerow died soon after the battle of Paniput, and was succeeded by his son Madhoorow, who died in 1772, and was succeeded by his son Narrainrow, who was murdered the following year by his uncle Ragobah, who was opposed in his designs on the throne by a combination of twelve chiefs. At the head of these was Ballajee Pundit, who became dewan or prime minister to the infant prince. Ragobah fled to Bombay, where he solicited and obtained, by means of an advantageous treaty, the aid of the British government. But this aid was ineffectual in seating the murderer upon the Mahratta throne. His crime had brought upon him the general obloquy of the nation; and his appeal to foreign aid united against him the whole confederate chiefs of the Mahratta empire. By the interference of the Bengal government, a treaty was concluded; but in 1777 the Bombay government again espoused the cause of Ragobah, and a war ensued which was terminated by a disgraceful convention, and Ragobah abandoned. A general war afterwards took place between the British and the Mahrattas, and was terminated by a treaty in 1782, by which every conquest was restored, except the island of Salsette. At this period the Mahrattas commenced hostile operations against all those independent states which lay between their territories and those of the Company; and in the course of six or seven years they were all subdued, by which the Mahratta frontier bordered with the British dominions. In 1785 they carried on an unsuccessful war with Tippoo, and were obliged to purchase peace by the cession of several valuable provinces, all of which they recovered by their alliance with the British in 1790. The posthumous and infant son of Madhoorow, who succeeded to the peishwaship when he came to maturity, died in 1795, and the two sons of Ragobah contended for the office. The cause of the eldest brother, named Bajeerow, was espoused by Scindia, by whose aid he was fixed on the throne; but he was permitted to enjoy nothing of the sovereignty but the name. In the year 1802 the united armies of the peishwa and Scindia were defeated by Holkar; and the former having taken refuge in the territory of the British, was, by their aid, reinstated on the throne, agreeing, in return, to a treaty offensive and defensive, and to receive into his pay a force of 6000 infantry, with the usual proportion of artillery attached, for the payment of which he assessed districts in the southern quarter of the country. From this period the peishwa, murmuring under his degradation into a state of dependence, cherished schemes of hostility against the British. The first overt act of hostility was the murder of the Guicowar's ambassador, through the agency of his ambassador Trimbuckjee. But his intrigues and schemes being discovered, he vowed the strictest fidelity in future; and in 1815 he delivered up his prime minister to the British. He soon contrived, however, to escape to the court of Poonah; and the peishwa, no longer dissembling, joined the confederacy which had at that time been formed amongst the native princes of India, namely, Scindia, Ameer Khan, Holkar, and the Berar Rajah, for the destruction of the British power. But this confederacy was signally overthrown; the peishwa's armies were entirely routed; and he, reduced to the character of a wandering fugitive, at last surrendered himself a prisoner to Sir John Malcolm, on condition of an allowance being assigned him. It was now resolved by the Anglo-Indian government to abolish the authority and the name of the peishwa, which had become a rallying point for the disaffected, and to occupy the whole of the Poonah dominions for the British nation, with the reservation of certain territories for the Satarah family. Thus was extinguished not only the political influence, but the name and authority, of the Mahratta state.

MAI, Angelo, a cardinal of the Roman Church, was born 7th March 1782, at Schilpario, a village of the province of Bergamo, in the Milanese territory. His parents were of the humblest peasant class; and he was placed, along with the other boys of the village, at the parish school, for the purpose of being initiated in the usual branches of elementary education. At this time, however, in consequence of the recent suppression of the Jesuit Society, and the dispersion of its members, a considerable number of ex-Jesuit priests were employed in the ordinary duties of the mission throughout Italy. One of these, Father Lewis Mozzi dei Capitani, a Milanese, who resided near Schilpario, was early struck by the remarkable abilities of Angelo Mai, and himself undertook to instruct him in Latin, Greek, and mathematics. About this time the Duke of Parma permitted the Jesuits to re-establish themselves at Colorno, in the duchy of Parma; and Mai, who was then about seventeen, accompanied his patron, Father Mozzi, to the college there opened, and with four youths of his native village, entered the novitiate of the society in 1799. He completed the novitiate in 1801, but remained at Colorno until 1804, when the society was more solemnly (though still only provisionally) re-established in the kingdom of Naples. To the college there founded Mai was sent as professor of Greek and Latin; but after somewhat more than a year and a half, he was transferred to Rome, when he completed his theological studies. Thence he was removed to Orvieto, where the bishop, M. Lambruschini, had invited the Jesuits to open a house. At Orvieto he was promoted to priest's orders; and remained partly engaged in teaching, partly in prosecuting his private studies, till 1808, when he was recalled to Rome. In that year, however, on the occupation of the Papal States by the French, an order was issued by the viceroy of Italy, requiring all natives of the kingdom of Italy to return to their respective provinces, and Mai was obliged to repair to Milan. As the Society was still unrecognised in the kingdom of Italy, Mai was compelled to seek for other occupation, and assumed the functions of a secular priest. After a time, through the influence of his first protector, Padre Mozzi, he was named an associate of the Ambrosian College, and soon afterwards a doctor of the Ambrosian Library. It is to his connection with this library that he is mainly indebted for his literary reputation.

Next to the unrivalled collection of the Vatican, the MS. treasures of the Ambrosian Library have long been celebrated in Italy for their number and importance. Enriched by contributions from the libraries of Bobbio, Lucca, Monte Cassino, and other great monasteries, the Ambrosian collection is now the depository of a large proportion of the literary treasures of the learned Benedictines of Italy; and although many of its MSS. had already been published or collated by the industrious editors of the seventeenth and eighteenth centuries, yet at the time when Mai was enrolled as an associate, it still contained enough to stimulate his curiosity and to exercise his learning. He had early acquired a taste for this branch of study under his first masters in the Jesuit Society, among whom were two learned Spanish fathers of some reputation in that department; and he now devoted a considerable time to a careful exploration of the Ambrosian MSS. His first publication was a Latin translation (accompanied by a critical commentary) of the recently discovered work of Isæus, *De Permutatione;* but he speedily relinquished the more beaten track of an ordinary editor or translator, and devoted himself to the then almost unknown department of palimpsest, or re-written MSS.—a class in which the Ambrosian Library is peculiarly rich. Up to this time but two or three palimpsest fragments had been deciphered and made public. In the course of a few years Mai was enabled to print two volumes of inedited fragments of Cicero's *Orations*, some orations of Lysimachus and Isæus, an interesting fragment of Plautus's lost comedy the *Vidularia*, and, above all, a large collection of the letters and other writings of Cornelius Fronto, the preceptor of Marcus Aurelius. The MS. from which these relics of Fronto were recovered had formerly belonged to the monastery of Bobbio, and was a translation of a part of the Acts of the Council of Chalcedon, written upon a series of palimpsest leaves, made up partly of an ancient MS. of Pliny the Younger, partly of an old commentator on Cicero, partly of some of the works of Lysimachus, and partly of letters of Fronto addressed to Antoninus Pius, Marcus Aurelius, Lucius Verus, and other friends,—all in a very disordered and mutilated condition, but yet sufficiently perfect to excite the curiosity of the learned throughout Europe. The most interesting circumstance, however, of the discovery is, that when Mai, some years later, was removed to the Vatican Library, he had the good fortune to find the remainder of this very palimpsest translation of the Acts of Chalcedon, *the counterpart of the Ambrosian palimpsest*, containing above a hundred additional letters of the same correspondence.

Meanwhile, the Jesuit Society had been formally revived by Pope Pius VII. on his restoration in 1814. But the services of Mai in his new position were so highly appreciated that, as he had never taken the solemn vows of the Order, he was induced to remain a member of the secular clergy. In 1819 he was invited to Rome to fill the office of chief keeper of the Vatican Library. Soon after his installation in this honourable and congenial office, he discovered that a MS. of St Augustine's *Enarrationes in Psalmo* was a palimpsest, the original of which had been no other than the long-sought work of Cicero *De Republica*. The commentary itself, unfortunately, was imperfect. It extended only from the 119th to the 140th psalm (the commentary on the ten remaining psalms being deficient); and even in the portion which remained there were gaps to the amount of sixty-four pages. Nevertheless, the skill and ingenuity of Mai recovered from these confused and obliterated fragments about one-fourth of the entire work, with which he interwove, in the edition which he published (Rome 1822), all the existing fragments of the original, collected from the numberless writers, sacred and profane, through whose writings they are scattered.

The design of the pope, however, in appointing Mai to the charge of the Vatican Library had been to engage him in a formal and systematic exploration of its contents, with a view to the publication of the most important remains of classical literature which still remain locked up in that great treasure-house. Mai, extending the plan, resolved to comprise in his collections the unpublished sacred as well as profane remains of the Vatican MSS., and, leaving to future scholars the task of critically editing, commentating, and translating, to secure for the world, in miscellaneous *Collectanea* similar to those of Muratori, Mabillon, Montfaucon, and their fellow-labourers, all that was really important among its inedited MSS. in every department of literature. On this plan he commenced, in 1825, a magnificent 4to publication,—*Scriptorum Veterum Nova Collectio é Vaticanis Codicibus Edita*,—which extended to 10 volumes, and comprises a vast number of unpublished remains of the Greek and Latin writers, sacred and profane. Several of the volumes are occupied with patristical remains. The second, which is almost entirely from a palimpsest source, contains an immense number of fragments of the lost books of the historians,—Polybius, Diodorus Siculus, Dionysius of Halicarnassus, Dion, Appian, and others, even so late as Dexippus and Eunapius.

In 1833 M. Mai was transferred from the office of Vatican librarian (in which he was succeeded by the celebrated linguist Mezzofanti) to that of secretary of the Propaganda; but he still continued his literary labours. He followed up the *Vaticana Collectio* by another collection in 8vo, equally miscellaneous, and indeed entirely similar in plan,—*Classici Auctores é Codicibus Vaticanis Editi*, 10 vols. 8vo (1828–38). In the year in which this work was brought to a close he was elevated to the cardinalate, and soon afterwards was named prefect of the Congregation of the Index, and of that of the Council of Trent, and eventually cardinal librarian of the Roman church.

The *Classici Auctores* was succeeded by a similar miscellany, but containing a larger amount of matter, *Spicilegium Romanum*, 10 vols. 8vo (1839–44). This collection, besides Greek and Latin writers, comprises also a few interesting Italian works, chiefly historical and biographical. His last publication was in 4to, *Nova Patrum Bibliotheca* (6 vols. 1845–53). It is almost exclusively patristical, and contains many highly important works, forming an indispensable supplement to almost all the existing patristical collections. Cardinal Mai had also undertaken to edit the celebrated Biblical *Codex Vaticanus*, and actually printed the text at the Propaganda press. He delayed its publication, however, with the intention of prefixing to the text an elaborate critical and historical introduction; but to the infinite disappointment of the learned, he died, leaving this great work incomplete, and indeed does not even appear to have made any progress in the preparation for it. Since his death, which occurred in his seventy-fourth year, at Albano, September 8, 1854, no trace of the expected biblical dissertations has been discovered. It is highly probable that the anxious and unsettled condition of political affairs at Rome during the years preceding his death, deprived him of the leisure or the spirit necessary for so laborious an undertaking. From the very nature of Cardinal Mai's collections it will be understood, that in very many of the works which he printed he contented himself with the mere rough work of publication. But in those which he undertook to edit critically, and especially in the *De Republica*, he appears as a master in the art. Even those works the text of which alone he printed, are accompanied by learned and judicious prefaces, which exhibit an amount of erudition such as few modern scholars can claim. His library was one of the most complete private collections in Rome. At his death he directed that it should be offered at half its estimated value to the Vatican Library, and that the proceeds of the sale should be applied to the use of the poor of his native village of Schilpario. (C. W. R.)

MAIANO, BENEDETTO DA, an eminent sculptor and architect, was born at Florence in 1424. He first became known as an inlayer of wood, and in this capacity he was employed at Naples by King Alphonso, and afterwards in Hungary by King Matthias Corvinus. Ambitious, however, to excel in a nobler art, he turned his attention to sculpture, and returning shortly after to Florence, he was employed by the magistrates of that city in the construction of their audience chamber. While sojourning for a short time in Naples, he executed a bas-relief in marble of the Annunciation. On his return to Florence, Maiano commenced one of his masterpieces, the marble pulpit of Santa Croce, ornamented with sculptured representations of the history of San Francesco. He was next employed in constructing the plan of the Palazzo Strozzo. Turning his attention about this time to architecture, he built, in addition to other structures, the portico of Madonna della Grazie, near Arezzo. After amassing a considerable fortune, Maiano died in 1498, and was buried in the church of San Lorenzo in Florence.

MAIDA, a small town of Naples, province of Calabria Ultra II., 8 miles S. of Nicastro, and chiefly famous on account of a victory gained here by the English over a superior French force on 4th July 1806. Pop. about 3000.

MAIDEN, an instrument anciently used for beheading criminals, resembling the guillotine of the French. It seems to have been first used in Britain within the limits of the forest of Hardwick. There is a machine of this kind in possession of the Society of Scottish Antiquaries at Edinburgh, introduced by the Regent Morton, who took a model of it as he passed through Halifax, and at length suffered by it himself. A machine precisely similar was used in Genoa in the beginning of the sixteenth century; and one is figured in the *Symbolicæ* of Bocchi, Bologna, 1574.

MAIDENHEAD, a municipal borough and market-town of England, county of Berks, on the S. bank of the Thames, 14 miles N.E. by E. of Reading, 22½ miles W. of London. It consists of one street about a mile long, well paved, and lighted with gas. The town has a guildhall, which is a fine building; a chapel of ease; places of worship belonging to the Baptists and Wesleyan Methodists; a national school; and several charitable institutions. The manufactures are unimportant; but the wealth of the surrounding country, and the position of the town on the high road between London and Oxford, render it a place of considerable trade, the principal articles of which are meal, malt, and timber. The market is held on Wednesday, and there are also three annual fairs. The neighbourhood is highly cultivated, and is studded with gentlemen's seats and villas. The high road here crosses the river by a fine stone bridge, and the Great Western Railway by a very elegant one of brick. The borough received its first charter from Edward III., and it is governed by a mayor, four aldermen, and twelve councillors. Pop. (1851) 3607.

MAIDSTONE, the county town of Kent, and a municipal and parliamentary borough, stands on a gentle slope on the right bank of the Medway, 34 miles E.S.E. from London. It was anciently called Caer Meguaid, or Medwig (the City of the Medway); and afterwards, by the Saxons, Medwegestan and Meddestane, whence it acquired its present name. It was formerly in the possession of the archbishops of Canterbury; and their Gothic palace, dating from 1348, is still standing, though considerably altered from its ancient form. In the civil war Maidstone was taken by the parliamentary forces under Fairfax in 1648. A college was founded here by Archbishop Courtenay in the time of Richard II., but was suppressed about the time of the Reformation. Maidstone has always returned two members to Parliament since the time of Edward VI., from whom, and from various succeeding monarchs down to George II., it received charters. The town consists of four main streets, meeting in the market-place, together with several smaller ones. The sloping character of the ground on which it is built keeps the town clean and dry, and it is well supplied with water from the Medway. Of the public buildings, the chief is the parish church, built in the fourteenth century, and reckoned one of the largest edifices of the kind in England. It has recently been restored in a very splendid style. There are, besides, various other places of worship for different denominations. It has also a county hall, an extensive gaol, erected lately at the cost of L.200,000, and covering 13 acres, a town-hall, a corn exchange, a theatre, ball-rooms, and other buildings. There is a school called All Saints College, founded in 1846, occupying a portion of the buildings of the college which formerly existed here; also a free grammar school, a Blue-coat and a Brown-coat school for clothing and educating poor children, national schools, &c. The only manufacture for which Maidstone is remarkable is that of paper, of which there are a number of mills in the neighbourhood. The surrounding country is extremely beautiful, by reason of its orchards and hop gardens; and the circumstance which has contributed most to the prosperity of the town is the fertility of the neighbourhood. The river is here crossed by an old bridge of seven arches, and is navigable for vessels of sixty tons up to the town. Maidstone is connected with London by a branch of the South-Eastern Railway, by which route the distance is 56 miles. Market-days, Thursday and Saturday. The borough is governed by a mayor, six aldermen, and eighteen councillors. Pop. (1851) 20,801.

MAILLA, Joseph-Anne-Marie de Moyriac de, a learned Jesuit, was born in Bugey, on the borders of Savoy, and appointed a missionary to China, whither he proceeded in 1703. At the age of twenty-eight he had acquired such skill in the characters, arts, sciences, mythology, and ancient books of the Chinese, as to astonish even the learned men of the celestial empire. Besides constructing maps of China, Chinese Tartary, and the Chinese provinces, Mailla also translated the *Great Annals of China* into French, and his MS. was transmitted to France in the year 1737. This work was published in 1737 in 13 volumes quarto, and is the first complete history of that extensive empire. Mailla died at Pekin on the 28th of June 1748, in the seventy-ninth year of his age.

MAI-MAITCHIN. See Kiachti.

MAIMBOURG, Louis, a celebrated Jesuit, descended from a noble family, was born at Nancy in 1610. At the age of sixteen he entered the Society of Jesus, and was sent to Rome to study theology. On his return to France, he became a classical teacher in the college of Rouen; but afterwards devoted himself to preaching, and occupied in turn the principal pulpits in the kingdom. Not until Maimbourg had reached the middle stage of life did he produce any of those historical works upon which his fame rests. In 1682 he appeared as a bold defender of the liberties of the Gallican church in his *Traité Historique de l'Eglise de Rome*, a treatise which caused the immediate expulsion of its author from the Order of the Jesuits by the command of Pope Innocent XI. As a compensation, however, for this misfortune, Maimbourg was presented by Louis XIV. with a pension, and with the abbey of St Victor at Paris as a place of retirement. He died there of apoplexy on the 13th August 1686, leaving unfinished his *Histoire du Schisme d'Angleterre.* A collection of Maimbourg's histories, published in 14 vols., Paris, 1686–87, includes, besides the work mentioned above,—*Histoire de l'Arianisme, Histoire des Iconoclastes, Histoire du Schisme des Grecs, Histoire des Croisades, Histoire de la Décadence de l'Empire, Histoire du Grand Schisme d'Occident, Histoire du Luthéranisme, Histoire du Calvinisme, Histoire de la Ligue, Histoire du Pontificat de Saint Grégoire le Grand*, and *Histoire du Pontificat de Saint Léon.* Although once in great repute, Maimbourg, as a historian, has no longer any authority; yet Voltaire, a critic by no means guilty of partiality to churchmen, says that Maimbourg "was formerly in too great vogue, and has been latterly in too great neglect."

MAIMONIDES, or Ben Maimon Moses, a celebrated Jewish rabbi, was born at Cordova in Spain, probably about 1131. After receiving the elements of his education from his father, he studied philosophy and medicine under the learned Arabians Thophail and Averroes. He also perused with avidity the ancient philosophers, especially Aristotle, and thus incurred the dislike and suspicion of his Jewish brethren. Soon after this he repaired to Egypt; and from remaining there during the rest of his life, he acquired the title of *Moses Ægyptius.* There he at first followed the vocation of a jeweller; but resorting afterwards to the practice of medicine, he became so eminent in this profession, that he was appointed chief physician to the Sultan Saladin. While holding this office, Maimonides is said to have also taught with great success in a school which he had founded. He died in Egypt at an advanced age. In addition to a thorough knowledge of philosophy and medicine, Maimonides possessed an acquaintance with mathematics, theology, and the jurisprudence of the Jews. He knew several languages, and wrote Arabic and Hebrew with facility. By his Jewish admirers he was surnamed "The Eagle of the Doctors," and "The Lamp of Israel." Of his numerous works three are chiefly notable. His "*Moreh Nevochim* (Teacher of the Perplexed"), written originally in Arabic, but afterwards translated into Hebrew, is an exposition of the obscure words, allusions, types, and allegories in Scripture. A translation into Latin by the younger Buxtorf, 4to, Basel, 1629, has been retranslated into English by Dr Townshend, London, 1827. The original Arabic, accompanied with a French translation, has been published under the title, *Le Guide des Egarés, traité de Théologie publié en Arabe avec Traduction et Notes par S. Munk*, 8vo, Paris, 1856. The Arabic text of the *Moreh Nevochim* exists in the Bodleian Library, Oxford. In *Yad Hazakah* ("The Strong Hand"), written in good Hebrew, Maimonides gives a digest of the Talmud, stripped of all its rabbinical fables. The best edition of this work is that in 4 vols. folio, Amsterdam, 1702. His *Perush Ha-Mishna* ("Commentary on the Mishna"), originally written in Arabic, has been often translated into Hebrew by different rabbis, and printed along with the *Mishna*. Part of this work, in the original Arabic, was published by Pococke, Oxford, 1655. MSS. of the works of Maimonides are found in the great libraries of Paris, Berlin, &c.

MAIN, MAINE, or MAYN (the ancient *Mœnus*), formed by the union in North Bavaria, about 14 miles N.W. of Bayreuth, of two streams, the Red and White Main, which have their sources in the Fichtelgebirge. It has a very irregular and winding course in a direction generally westerly, and falls into the Rhine nearly opposite to Mentz. It is about 280 miles in length, and is navigable as far as its junction with the Regnitz, near Bamberg, about 240 miles from its mouth. As early as 793 Charlemagne had projected the formation of a canal between the Altmühl and the Pegnitz, an affluent of the Regnitz, and so connecting the Main and the Danube; but it is only very recently that this has been effected. The chief tributaries of the Mayn are,—the Regnitz, Tauber, Mümling, and Gersprenz from the S., and the Rodach, Saale, Kinzig and Nidda from the N. The principal towns on or near its banks are Bayreuth, Bamberg, Würzburg, Aschaffenburg, Hanau, Offenbach, and Frankfort.

MAINE, one of the United States of North America, lying between N. Lat. 43. 5. and 47. 30., W. Long. 66. 50. and 71., and bounded on the N. by the St John River, which separates it from Canada; on the E. by New Brunswick; on the S.E. and S. by the Atlantic; and on the W. by the state of New Hampshire and Canada. Length about 200 miles; average breadth 160; area 31,766 square miles. It is the largest of the states of New England, of which it comprises nearly one-half. The face of the country is covered with an undulating surface of hill and dale; and although it has no marked mountain ridge, a succession of isolated hills, which form the termination of the White Mountains in the neighbouring state, extends across the country towards the N.E., and forms the watershed between the basin of the St John on the N., and the rivers that flow to the Atlantic on the S. Of the mountain summits, the highest is Katahdin Mountain, which attains the elevation of 5385 feet above the sea. The sea-coast is bold and precipitous, frequently indented with bays and inlets, many of which form very good harbours. The coast is also skirted with islands, for the most part of small size, and said to amount to the number of 365. The fishing in these parts is very good. The most marked natural feature of the state, however, is its rivers and lakes, which are calculated to cover one-tenth of the entire area. The largest rivers are the Penobscot and the Kennebec, which flow from the elevations in the centre in a S.W. direction, and discharge their waters into the Atlantic. The former, which is the more easterly of the two, is the largest river in the state, and has a length of 350 miles. The rivers of Maine are remarkable for their abrupt windings and falls, which, however, do not prevent the conveyance of timber rafts from the thick forests with which the interior is covered, and which supply one of the principal articles of export. The rivers are also useful as affording water-power to the many mills on their banks. The Penobscot is navigable for the largest vessels as far as Bangor, 60 miles from the sea; but for several months in the winter it is blocked up with ice. The lakes are very numerous, and remarkable for their irregular shapes, and for the wild beauty of their scenery. The largest is Moosehead Lake, about 50 miles in length, and varying from 5 to 15 in breadth. When the country becomes better inhabited, these sheets of water are likely to prove most useful as means of communication.

Geologically, the state of Maine is chiefly composed of primary rocks, though towards the E. there is to be found a tract of land of the secondary formation. The rocky barrier which extends along the sea-coast is composed of igneous formations, and granite is found in great abundance throughout the state. Marble and limestone are also extensively quarried in the country; indeed, it is from Maine principally that the whole of the states are supplied with lime. Trap dykes occur frequently; and on many accounts this district is interesting to the geologist. Iron is found of an excellent quality, and in considerable abundance; some traces of coal have also been observed; and on some of the eastern tributaries of the Penobscot gold has been found, but not to any great amount. The soil is generally rich and fertile, though towards the coast and among the mountains it is sandy and barren. The best soil is found in the country lying between the Penobscot and the Kennebec; and the chief articles of agriculture are potatoes, oats, and Indian corn. Of the natural products, the most remarkable are the forests of white pine, which are so extensive as to give to one district the name of "White Pine Land." Oak, ash, and beech trees, also grow in great quantities; and this, along with other circumstances, has contributed to render Maine the state most remarkable for ship-building in the Union. During the year ending 30th June 1855, 639 vessels of various kinds, including 6 steamers, and having an aggregate burden of 215,904 tons, were built in this state; while the total number of vessels built in all the other states of the Union during that period was only 1385, with an aggregate burden of 367,546 tons, or less than double the amount of tonnage built in this state alone. The climate in winter is very severe, the frost lasting from December to April, and so intense, that the largest rivers may be crossed on the ice; while in summer the heat is very great. The thermometer ranges between 100° in summer, and 28° below zero in winter; but the country is remarkably healthy; and towards the coast the severity of the cold is moderated by its proximity to the gulf stream. The inhabitants are principally the descendants of the ancient British colonists, though there are still about 500 of the original Indians, dwelling chiefly on the islands of the Penobscot, which belong to them, and drawing a considerable annuity from the government. There are also many emigrants from other countries, but by no means in such large proportions as in most of the other states. This state is not so extensively engaged in manufactures as some others in New England. The principal branches followed here are the iron, woollen, and cotton manufactures, besides ship-building and the tanning of leather. The products of the iron forges, &c., were, in 1850, 5175 tons, valued at L.62,837; of the cotton factories, 32,852,556 yards, valued at L.540,908; of the woollen manufactures, 1,023,020 yards, valued at L.157,139; and of the tanneries, leather to the value of L.340,633. Its commerce, however, is considerable, owing to the number and excellence of its harbours. The principal articles of export are timber and fish. The total value of exports during the year ending June 30, 1855, was L.937,868, comprising

L.529,794 of domestic, and L.408,074 of foreign produce. Of the imports at the same date, the total value was L.610,084, of which L.287,336 were conveyed in American, and L.331,748 in foreign vessels.

This state is divided into 13 counties. The capital is Augusta, on the Kennebec, though the largest and most commercial town is Portland, on Casco Bay. The extent of railways in the state in January 1856 was about 480 miles, the principal lines being the Androscoggin and Kennebec, the Atlantic and St Lawrence, the Kennebec and Portland, and the Penobscot and Kennebec; and there is also a canal of 50 miles in length, uniting Portland with Sebugo, Brandy, and Long Ponds. The government of Maine is in the hands of a governor, who is elected annually by popular vote, and he is aided by a council of 7, chosen by the legislature by ballot. The legislature consists of a Senate of 31, and of a House of Representatives of 151 members, both also elected annually. The right of suffrage is possessed by all males above twenty-one years of age, who have been resident in the district for three months immediately before the election. The constitution of the judiciary courts has been altered in 1852. The state is divided into three districts, and the courts are held annually at Portland for the western, at Augusta for the middle, and at Bangor for the eastern district. Among the public institutions are,—the state prison at Thomastown, which is managed on the silent system, and where the prisoners are employed in stone-cutting and quarrying; the state reform school, opened in 1853 at Cape Elizabeth for juvenile delinquents, where they are employed in various labours; and the lunatic asylum at Augusta, opened in 1840. For the purposes of education the state has a separate fund, collected from the various sources, of which there was expended for the year ending April 1, 1855, L.102,304. According to the census of 1850, there were 4042 public schools in the state, besides 131 academies and other schools, 2 colleges, 1 theological seminary, and 1 medical school. The whole value of property in Maine in 1850 was L.20,159,556; and the public debt amounted in 1856 to L.145,000. The number of churches in the state in 1850 was 851, of which there belonged to the Baptists 283, to the Christians 9, to the Congregationalists 12, to the Episcopalians 8, to the Free Church 19, to the Friends 4, to the Methodists 171, to the Presbyterians 7, to the Roman Catholics 11, to the Union Church 83, to the Unitarians 15, and to the Universalists 53; giving, on an average, one church to every 685 persons. The total amount of church sittings was 321,167. The first settlement effected in Maine was at Phippsburg in 1607; but this was soon afterwards abandoned, and the country was colonized from the neighbouring districts. In the latter part of the seventeenth century this state was the occasion and the scene of many conflicts between the British and the French, till it was finally secured to the former by the peace of Utrecht in 1712, at which time it was attached to Massachusetts. The town of Portland was bombarded by the British in 1775, when much property was destroyed. In 1820 this state was separated from Massachusetts, and received as a distinct state into the Union; and in 1842, after much negotiation, the boundaries between it and Canada were finally settled between Great Britain and the United States. Pop. (1850) white, 581,763; coloured, 1325; total, 583,088.

Maine, an old province in the W. of France, bounded on the N. by Normandy and Perche, on the E. by Orleanais, on the S. by Touraine and Anjou, and on the W. by Bretagne. It was divided into Upper and Lower Maine, and formed, along with Perche, the military government of Maine. It now forms, with the addition of some parts of Higher Anjou, the department of Sarthe and Mayenne.

MAINE DE BIRAN, Francois-Pierre-Gonthier, a distinguished philosopher of France, the son of a physician, was born at Bergerac on the 29th November 1766. After studying with distinction under the *doctrinaires* of Perigueux, he entered the Life-Guards of Louis XVI., and was present at Versailles on the notable 5th and 6th of October 1789. On the breaking up of the *garde du corps*, Maine de Biran retired to his patrimonial inheritance of Grateloup, near Bergerac, where his sequestered residence and limited income preserved him from the horrors of the Revolution. It was at this period that, as he says himself, he "passed *per saltum* from frivolity to philosophy." The forced leisure of this fearful time decided the vocation of his life. He combined, in a more than ordinary degree, subtle sensitiveness to external influences with singular acuteness in surveying and analyzing internal phenomena. The modes of the mind and their organic causes or conditions were alike submitted to his scrutiny. He began his philosophical studies with psychology, and he made psychology the study of his life. When the Reign of Terror was succeeded by calmer days, Maine de Biran was called to take part in the administrative and political affairs of his country. After his exclusion from the Council of the Five Hundred, on being suspected of royalism, he took part with his friend Lainé in the commission of 1813, which gave expression for the first time to direct opposition to the will of the emperor. Under the Restoration, Maine de Biran held the office of treasurer to the Chamber of Deputies, and habitually retired during the autumn recess to his native district to pursue his favourite study. He died 16th July 1824.

Maine de Biran ranks among the earliest of the rational psychologists of France, who, in the beginning of the present century, raised a protest against the exclusive sensationalism of the school of Condillac. Maine de Biran was originally a disciple of Cabanis and De Tracy, but afterwards abandoned their system to adopt an absolute spiritualism closely resembling that of Leibnitz. He rejected, however, the pre-established harmony of the German philosopher, and endeavoured to explain the phenomena which that celebrated theory was meant to rationalize, by resolving mind and matter into forces identical in their nature, but differing in the modes of their activity. All objects, external and internal, are recognised by consciousness only as forces, more or less active, more or less passive. To explain the phenomena of external perception on those principles, is accordingly an easy matter with Maine de Biran. You can dispense with the mediate object of the representationalists; you have no need of the hypothesis of occasional causes or of pre-established harmony; you are saved the humiliation of taking refuge in your ignorance, and bowing down before a mystery; your dead matter and living mind are not two distinct substances,—the relations of body and soul are only relations of forces of action and reaction. The theory of causation of Maine de Biran is the portion of his philosophy which is most generally known in this country; and Sir W. Hamilton, in commenting on it, terms its author "one of the acutest metaphysicians of France." The casual judgment is regarded by Maine de Biran as an original *à posteriori* cognition, given through a self-consciousness of the efficiency of our own volitions. M. Cousin, who is constant in his laudation of the originality of his countryman, characterizes him as "the greatest metaphysician of France since Malebranche." A complete edition of the *Œuvres Philosophiques de Maine de Biran* was published by M. V. Cousin, 4 vols. 8vo, Paris, 1841.

MAINE-ET-LOIRE, a department in the W. of France, including the most part of the province of Anjou and the W. part of Touraine, and lying between N. Lat. 46. 59. and 47. 45., and between 0. 15. E. and 1. 18. W. Long. Its greatest length is 77 miles, its greatest breadth 60, and its area 2756 square miles. It is bounded on the N. by the departments of Mayenne and Sarthe, on the E. by that of Indre-et-Loire, on the S. by those of the Vienne, the Deux Sevres, and La Vendée, and on the W. by that of the Loire-Inferieure. This department receives its name from the two rivers Maine and Loire, which unite here. There are no mountains of any importance in the department, but the ground consists of an undulating plain, diversified here and there by vine-covered hills. A small portion, however, at the N.W. extremity is occupied by the hills which separate the valleys of the Vilaine and the Loire, and the southern part is covered by a continuation of the hills of Gâtine. The most important river in the department is the Loire, which passes through it from E. to W., dividing it into two nearly equal parts. Besides this, it is watered by the Authion, the Maine, the Sarthe, the Mayenne with its tributary the Oudon, the Erdre, and the Thouet in the N.; while in the S. there may be noticed the Layon, the Erve, the Sevre-Nantaise, and the Moine, several of which are navigable rivers, while they all contribute to the fertility of the neighbouring country. The department is very productive, and the principal occupation of the inhabitants is agriculture. The corn produced is considerably more than sufficient to supply the wants of the inhabitants. The principal of the other productions are,—potatoes, hemp, flax, nuts, and fruits of various kinds. About 11,000,000 gallons of wine are made annually, besides a considerable amount of cider. The forests of this department are extensive, and consist principally of oak and beech. The pasturage is very good, and large quantities of live stock are annually reared, especially along the banks of the principal rivers. It has been calculated that there are in this department 210,000 head of large cattle, 200,000 sheep, 86,000 pigs, 4300 goats, 40,000 horses, and 3600 mules and asses. The forests abound in deer and wild boars, and there are also found numbers of foxes and weasels. The game and fish are very plentiful. Coal mining is carried on to a considerable extent, but the quantity produced, amounting to about 200,000 cwt. annually, is entirely consumed in the department. There are also considerable slate mines, situated chiefly round the town of Angers, where they give employment to 3000 workmen, and produce annually about 80,000,000 slates. Iron is also found, though in no great abundance; but it furnishes materials for several furnaces. There are also quarries of granite, marble, sandstone, limestone, &c. There is not much manufacturing industry in this department, but what there is has its chief seat about Cholet; and its principal products are linen, cotton, and woollen stuffs; Maine-et-Loire being especially famous for its handkerchiefs. There are also several breweries and distilleries, as well as tanneries and manufactories of bricks, tiles, pottery, and other articles. The trade of the district consists chiefly in cattle, grain, wines, linen, and dried fruit.

This country was anciently occupied by the Andes, or Andecavi, from whom the name Anjou is derived; and many Gallic monuments are still to be seen in the department. It was afterwards in the hands of the Romans, who have also left traces of their occupation. During the time of the Revolution this neighbourhood is remarkable as having been the seat of the war of La Vendée. This department is divided into five arrondissements as follows:—

	Cantons.	Communes.	Population.
Angers	9	89	154,945
Baugé	6	66	79,713
Segré	5	61	62,080
Beaupréau	7	76	121,375
Saumur	7	83	97,339
Total	34	375	515,452

MAINTENON, Madame de, descended from the ancient family of D'Aubigné, was born in 1635 in the prison of Niort in Poitou, where her profligate father was then confined. Her parents by misfortunes being unable to support her, she was intrusted to the care of her mother's relations; and, to escape this state of dependence, she was induced, in 1651, to marry the Abbé Scarron, a celebrated burlesque writer, who was deformed, infirm, and, as she insinuates in one of her letters, impotent, with no other means of support than a small pension allowed him by the court. When Scarron died in 1660, she found herself as indigent as she had been before her marriage. But Louis XIV. afterwards made choice of her to take charge of the education of the young Duke of Maine, his son by Madame de Montespan, and he was so charmed with the letters she wrote on this occasion, that he bought her the lands of Maintenon; and finding that she was pleased with the acquisition, called her publicly *Madame de Maintenon.* About the close of the year 1685, Louis XIV., being then in his forty-eighth, whilst she was in her fiftieth year, raised her from the condition of a mistress to that of a wife. By consummate art and address, concealed under a mask of affected simplicity and piety, she attained the grand object of her ambition; and though not publicly acknowledged, became in reality the second person in the state, and took part in some of the most disgraceful acts of that reign. She prevailed on Louis to found a religious community at St Cyr, for the education of 300 young ladies of quality; and on the death of Louis in 1715, she retired thither, where she spent the rest of her days in acts of devotion. It appears that her husband left no fixed provision for her, contenting himself with recommending her to the Duke of Orleans. She accepted a pension of 80,000 livres, which was punctually paid her till her death, which took place in 1719. A collection of her letters has been published, and translated into English.

MAIRWARRA, or *Realm of the Mairs*, in Hindustan, a mountainous tract, consisting of a number of parallel ridges extending in a direction from N.E. to S.W., and constituting that portion of the Aravulli range which lies between Komulmer and Ajmere, a space of about 90 miles in length, and varying in breadth from 6 to 20. The tract is interposed between the Rajpoot states of Oodeypore and Joudpore. Its north-eastern extremity is in Lat. 26. 10., Long. 74. 30.; its south-western in Lat. 25. 25., Long. 73. 50. Mairwarra was ceded to the British in 1818 by Scindia, but the states of Oodeypore and Joudpore having urged claims to a portion of the country, their validity was hastily and unadvisedly recognised. The inconvenience of three independent states claiming to exercise the powers of government in a country so circumstanced was, however, subsequently mitigated by arrangements under which the whole was placed under British management. The principal place in the district is the newly-established town of Nya Nugga, which promises to be the seat of considerable trade. British Mairwarra contains an area of 282 square miles, with a population of 37,715. The portion allotted to Oodeypore has an area of 305 square miles, and that belonging to Joudpore a superficial extent of about 67 square miles.

MAISTRE, Louis Isaac le. (See Sacy.)

Maistre, *Count Joseph Maire de*, a statesman and philosopher, was born at Chambery in Piedmont, on the 1st April 1753. His father, who held the honourable office of president of the senate of Savoy, directed his education with much care; and the industry and success of the son amply rewarded the solicitude of the parent. Having completed his education at the university of Turin with great distinction at the age of twenty, the following year saw him elevated to the rank of a magistrate, and in 1788 he was promoted to the dignity of a senator. On the French invasion in 1792 he was compelled to take refuge in Lausanne, where he remained till 1797, when he returned to Piedmont, only to leave it again for Venice. He remained in the latter city till 1800, when a call from the King of Sardinia to occupy an important political position in connection with the government of that kingdom, induced him to embark again in public life. Count de Maistre was sent as an ambassador to St Petersburg in 1803, where he remained till 1817. He died on the 26th February 1821, in his sixty-eighth year.

The writings of Count de Maistre are of a twofold character. The *Soirées de Saint Petersbourg*, and the *Examen de la Philosophie de Bacon*, belong more properly to philosophy; while the *Essai sur le Principe Générateur des Constitutions Politiques; Le Pape;* the *Considerations sur la France*, &c., are devoted to an exposition and defence of the political and social views of the author. The *Soirées*—which, by its popular form, its nervous and picturesque style, and the vigorous talent and pleasant wit which pervade it, exerted great influence—runs through a series of subtle metaphysical questions, handled with the apparent ease of a man of the world, and with all the grace of unstudied conversation. But his philosophy is more the reflex of his social ideas and political feelings than the product of calm reflection and steady adherence to the phenomena of observation. The principal design of De Maistre's philosophy is to justify or explain the temporal government of Providence; to show that the sufferings to which mankind are subjected are in no wise contradictory of the attributes of the Deity. He maintains that the good and the bad are alike subject to calamities, but that the good have less to suffer than the bad; that the good man suffers not as good, but as man; that man suffers in consequence of original sin; and that our only deliverance consists in personal prayer and the intercession and merits of the good employed in our behalf. He sums up his scheme of moral government by alleging, that "sovereignty and punishment are the two poles upon which God has poised the world." As for his religious and political sentiments, he advocates the divine right of legitimate sovereigns, passive obedience, the authority of the church in matters of faith, the supremacy of the pope, and the superiority of ecclesiastical over temporary authority. His system betrays two peculiar tendencies,—the one towards asceticism, the other towards mysticism. A complete edition of De Maistre's works was published at Paris 1821–36.

MAITLAND, Sir Richard, a cultivator and preserver of Scottish poetry, was the son of William Maitland of Lethington, and of a daughter of George Lord Seaton. He was born in 1496, and after passing through a regular course of study at the university of St Andrews, he repaired to France, in accordance with the custom of that age, to finish his education. There he devoted himself chiefly to the study of law. On his return to Scotland, Maitland successively held office under James V., the Regent Arran, and Mary of Guise. In the government of the last, according to Sir John Scot, he was lord privy seal. He was appointed an extraordinary lord of session in 1551, and was knighted soon afterwards. In 1561 he celebrated the landing of Queen Mary by his ode on *The Quenis Arryvale in Scotland*, and from this poem we learn that its author had already lost his sight. Yet this deprivation, interfering to no great extent with his professional activity, did not retard his promotion. In this same year he was nominated an ordinary lord of session; and in 1562 a member of the privy council and lord privy seal. This last office he resigned in 1567 in favour of his second son, afterwards Lord Thirlstane. The blindness, as well as the peaceful disposition of Sir Richard Maitland, prevented him from mingling in the civil broils that followed the death of Darnley and the marriage of the queen with Bothwell. Yet, on account of the conduct of his eldest son, the famous secretary of Mary, his estate was seized by the king's party, and not till after the fall of the Regent Morton was it restored. In 1583 he received from the lords of session an exemption from regular attendance on his judicial duties, and he retired of his own accord in 1584. He died in 1586, at the age of ninety. Sir Richard Maitland's claim to notice rests on his valuable collection of Scottish poetry, still preserved in manuscript in the Pepysian Library, Magdalene College, Cambridge. It consists of two volumes, the one a folio, containing 176 pieces, and the other a quarto, containing 96. An edition of Maitland's own poems was published in 1830 by the Maitland Club, a society of literary antiquaries who have assumed his name.

MAIZE, or Indian Corn, the *Zea Mays* of botanists, a monœcious grass of the natural order *Graminaceæ* (see Botany, p. 215), is a native of tropical America, found in its wild state in Paraguay and Chile. Like some others of the same order, its stamens and pistils are in different flowers on the same plant; the stameniferous flowers are borne on the top of the plant, and the pistilliferous ones proceed from the axils of the leaves. The leaves are broad, and are suspended from large rough sheaths which surround the stem. The ripe grains, which are regularly arranged in rows, the one above the other, are compressed at the sides and flattened at the top. Their colour is for the most part pale yellow; some, however, are white, some blood-red, some purple, and some party-coloured. A plant generally has two full ears, varying greatly in the number of grains. Some ears have been known to contain the enormous number of 800 grains. The height of the stems varies from 2 feet to 8 or 10. The floral envelope of the pistil flower is extensively used in Southern Europe for packing oranges and lemons; and the Spaniards of South America contrive, by rolling tobacco into small squares, cut from the thin covers of the grain, to fashion for themselves agreeable cigarettos. Paper of a very excellent quality has been manufactured from the perianths of the maize.

The cultivation of maize has, within the last century, increased to an enormous extent over the American continent, and throughout most parts of Asia, Africa, and Southern Europe. It requires but little labour for its cultivation, and forms an exceedingly wholesome and nutritive diet. Although deficient in gluten, it is nevertheless made into cakes in North America, which are very highly esteemed. Some have advocated the introduction of maize as one of our regular crops in this country; but agriculturists have hitherto been of opinion, that none of its varieties could be ripened in the ordinary seasons of these islands. (See Agriculture, p. 313.) This supposition has recently been proved to be without foundation, by an experiment tried in the summer of 1850, by Mr Keene, on a crop of forty-day maize in St James's Park, London. The seed, which he had introduced from the Pyrenees, was put in the ground on the 24th May, and notwithstanding various drawbacks incidental to the locality, the crop was harvested on the 10th October, "the grain perfectly formed, full and ripe, and the cobs much finer than those grown on the Continent." (*Year-Book of Facts* for 1850, p. 246.) The amount of crop was at the rate of 50 bushels per acre, and the bread formed from it could be had in England at a cost of a halfpenny the pound. It is calculated that 30 acres of average soil, properly drained and sown with maize, would be worth L.400. It is supposed, however, that in the present state of things, maize could be purchased in the home market at a less sum than it could be cultivated, seeing that it can be raised in Ohio at 6d. the bushel of 56 lb., at a good profit. About two-thirds of the maize crop of the Americans are grown for exportation. The quantities of Indian corn or maize entered for home consumption, and chargeable with duty as a British import during the past three years, were as follows:—In 1854, 1,358,380 qrs.; in 1855, 1,224,281 qrs.; in 1856, 1,788,212 qrs. The importation of Indian-corn meal during the same time was as follows:—In 1854, 55,963 cwts.; in 1855, 12,154 cwts.; in

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1856, 7885 cwts. (See CORN LAWS AND CORN TRADE, p. 395. See also a pamphlet entitled *Facts for Farmers: Maize, its Culture and Uses, &c.*, Longman and Co.)

MAJESTY, a title of honour derived from the Romans, among whom *majestas* stood for the highest power and dignity of the people. *Majesty* was ascribed to the dictator, consul, and senate, and to persons or bodies vested with legislative power, in so far as they were the representatives of the sovereign public. At the fall of the republic, the name and dignity of *majesty* passed over to the emperors, and the title of *dignitas* was given to the magistrates. The attribute of *majesty* was not given to kings till much later. It was used first by the German emperors, and was introduced into France under Henry II., and into England under Henry VIII. The Emperor of Austria has the title of *K. K. Majestat* (Kaiserlich-Königliche-Majestat), Imperial Royal Majesty. The Pope conferred the title of *Apostolical Majesty* on Stephen, Duke of Hungary, and on Maria-Theresa; of *Catholic Majesty* on Ferdinand and Isabella of Spain; of *Most Christian Majesty* on the kings of France after Louis XI.; and of *Most Faithful Majesty* on the kings of Portugal after John V.

Majesty is now used conventionally as the title of European emperors and kings, with the exception of the Turkish Sultan, whose title is that of *Highness.*

MAJOR, in military affairs, a field-officer, next in rank above a captain, and inferior to a lieutenant-colonel. The major of a regiment assists the lieutenant-colonel, but has no positive duties in the presence of that officer. An officer must be six years in the service before he can be promoted to a majority. (See ARMY, and COMMISSION.)

MAJOR and *Minor*, in *Music*. See MUSIC, §§ *Intervals, Scales.*

MAJOR, or MAIR, JOHN, a scholastic divine and historian, was born about 1470 at the village of Cleghorn, near North Berwick. After attending for a short time at Christ's College, Cambridge, he entered the university of Paris in 1493. There he studied successively at the colleges of St Barbe and Montaigu, and graduated as A.M. in 1496. Chosen a doctor in 1505, he lectured on philosophy in the latter college, and numbered among his regular auditors the principals Jacques Almain, Robert Cenalis, and Jerome de Hangest. Soon after this, Major seems to have returned to his native country; and in 1518 he is found discharging the office of principal of the university of Glasgow. In his joint capacity of professor of theology, he became in 1522 the preceptor of John Knox. He was promoted to a chair in the university of St Andrews in the following year, and there, in 1525, George Buchanan was one of his pupils. Not long after this, Major removed once more to Paris, but returned to St Andrews in 1530, and became principal or provost of St Salvator's College in 1533. In this office he died about 1550.

The following is a list of Major's principal works:—*In Libros Sententiarum Commentarius*, published in 4 vols., Paris, 1509, 1510, 1517, 1519; *De Historia Gentis Scotorum libri sex*, Paris, 1521; *Commentarius in Physica Aristotelis*, Paris, 1526; and *In Quatuor Evangelia Expositiones Luculcutæ*, Paris, 1529. During his residence in France, Major had imbibed very liberal opinions on civil and ecclesiastical government; and from him it is probable that Knox and Buchanan first received those political principles, which afterwards in their separate spheres they so ably defended. As a writer, he is characterized by small erudition, no independence of thought, and a style bald and inelegant.

MAJORCA, MALLORCA, or MAYORCA, an island belonging to Spain, in the Mediterranean, the largest of the Balearic group, lies between N. Lat. 39. 16. and 39. 57., E. Long. 2. 20. and 3. 30. Its shape is that of a trapezoid, the vertices of the angles being directed to the cardinal points. Its length, from Cap de Pera to Grozer, is about 60 miles; and its breadth, from Palma to Alcudia, about 33. The N.E. portion of the island is very mountainous, the S.W. portion more level; though there occur in the latter isolated peaks of considerable height. The highest peak of the island, Puig Major d'en Torrella, has an elevation of 5120 feet above the level of the sea. The climate of the different districts varies considerably; the western partido, Palma, enjoying a much milder temperature than the central and eastern partidos, Inca and Manacor, as its surface is also more wooded and picturesque. It contains the towns of Valdemoza and Soller, which attract many strangers by the geniality of the air. The heats of summer are tempered by the sea breezes, while the northern coast is visited in winter by very violent gales. The coast facing the continent is generally steep, flatter towards the E., and indented with capacious harbours, that of Palma, the capital, being the largest.

The rocks of this island are limestone, and the mountains present the picturesque appearances usually remarked in that formation. There are quarries of marble, of various grains and colours, those of Santagny, in the partido of Manacor, being especially celebrated; and there are some mines of lead, iron, and cinnabar.

The inhabitants are almost wholly devoted to agriculture, and most of the arable land in the island is under cultivation. The mountains are terraced, and the old pine woods are fast disappearing and giving place to the olive, the vine, and the almond tree, fields of wheat and flax, or to orchards of figs, oranges, &c. Much saffron is also grown. The oil harvest is very considerable, averaging 650,000 gallons yearly. The wines are light, but excellent, especially the Muscadel and Montona. Mules are used in the agriculture and traffic of the island. The oxen are small, but the sheep large and well fleeced. There is abundance of poultry, and of small game. There is not much industry beyond that engaged in or immediately dependent upon agriculture. A good deal of brandy is made and exported. Very superior woollen and linen cloths are made. The silk-worm is reared, and there is a considerable manufacture of silk. Their cabinet-work is celebrated.

In 1846 the population amounted to 179,753. There are two cities, Palma and Alcudia; Palma is an episcopal see. The largest remaining towns are,—Lluchmayor, Campos, Santagny, Inca, and Pollenza, anciently a Roman colony. The inhabitants are industrious and hospitable, and pique themselves much on their loyalty and orthodoxy. Castilian is spoken by the upper and commercial classes; the lower and agricultural employ a dialect resembling that of the Catalans, with whom also their general appearance and manners seem to connect them.

The early history of the Balearic Isles is obscure. The origin of the name itself is doubtful, some deriving it from the Phœnician god Bal (Baal), others connecting it, through the Greek, with their celebrated skill in the use of the sling. The Balearic slingers were useful auxiliaries to the Carthaginians, and contributed to the victories of Trebia, Thrasymenus, and Cannæ. But it was their piracies which drew on them the Roman vengeance. About 123 B.C. they were subjected by Q. C. Metellus, who established a Roman colony at Pollenza, introducing Iberians, and erecting an aqueduct 6 miles in length, the remains of which still exist. Metellus also introduced the Roman tongue, and the cultivation of the olive. By the Romans the two principal islands were called Major and Minor, whence their modern names. In A.D. 423 they were taken possession of by the Vandals, and in 798 by the Moors. The Balearic Isles became a separate Moorish kingdom in 1009; which, becoming extremely obnoxious for piracy, was the object of a crusade directed against it by Pope Pascal II., in which the Catalans took the lead. This expedition was frustrated at the time, but was resumed by Don Jaime, King of Aragon, and the Moors expelled in 1232. During their occupation, the island was populous and productive, and an active commerce was carried on with Spain and Africa. Don Jaime conferred the sovereignty of the isles on his third son, under whom and his successors they formed an independent kingdom up to 1349. Thenceforth their history is that of Spain. In 1521 an insurrection of the peasantry against the nobility, whom they massacred, took place in Majorca, and was not suppressed without much bloodshed. In the war of the Spanish succession all the islands declared for Charles; the Duke of Anjou had no footing anywhere save in the citadel of Mahon. Minorca was reduced by Count Villars in 1707; but it was not till June 1715 that Majorca was subjugated. When the French invaded Spain in 1808, the Mallorquins did not remain indifferent; the governor, D. Juan Miguel de Vives, announced, amid universal acclamation, his resolution to adhere to Ferdinand VII. At first the Junta would take no active part in the war, retaining the corps of volunteers that were formed for the defence of the island; but finding it quite secure, they transferred them successively to the Peninsula to reinforce the allies. Such was the animosity excited against the French when their excesses were known to the Mallorquins, that some of the French prisoners, conducted thither in 1810, had to be transferred with all speed to the island of Cabrera, a transference which was not effected before some of them had been killed.

MAKALLAH or Macullah, a town on the S. coast of Arabia, N. Lat. 14. 31., E. Long. 49. 6., 300 miles E.N.E. of Cape Aden, and about the same distance S. of Mareb. The town stands on a narrow projecting ledge of rocks, in the centre of a bay of the same name. Its appearance, as seen from the sea, is very grand, and it is defended by six square towers on the height above, as well as by walls. The bay affords very good shelter for vessels, being protected on the S.E. by a promontory bearing the same name, at the distance of 4 miles; and towards the W. there is a reef forming a secure harbour, much frequented by coasting vessels. Immediately behind the town rise a series of limestone cliffs to the height of 300 feet, beyond which is a lofty mountain called Jebel Gharrah, 1300 feet above the sea. The town is chiefly composed of huts, along with a few stone houses and two mosques. A considerable traffic is carried on here; for, besides supplying vessels with provisions, it exports gum, hides, senna, &c.; and imports cotton, lead, and iron from Bombay, and sheep, calves, honey, and slaves from Kosseir and Berberah. The inhabitants of this town are very varied; for besides the native Arabs, who do not comprise more than half of the population, there are Banyans, in whose hands most of the trade with India is; Karachies from the Persian Gulf; Sahawili from the E. coast of Africa; and Somali from the coast opposite Aden. Pop. estimated at about 4500.

MAKO, or Makovia, a market-town in East Hungary, in the palatinate of Cnasad, on the Maros, 9 miles W. by N. of Cnasad, and 21 miles E.S.E. of Szegedin. It is the seat of a bishop; and has a Roman Catholic church, a Greek church, a Protestant church and gymnasium, and a Jewish synagogue. The town contains a court-house and county buildings, and a handsome barracks recently erected. The neighbourhood is very fertile, producing corn and wine, and affording excellent pasturage for cattle. Many of the inhabitants subsist by river fishing. A considerable trade is carried on in the products of the vicinity. Pop. (1851) 22,611, of whom more than half were Protestants, and a considerable number Jews.

MAKRI, Macri, or Makry, a seaport-town on the S.W. coast of Anatolia, Asiatic Turkey, N. Lat. 36. 37., E. Long. 29. 9., being 52 miles E.N.E. of Rhodes, and 125 S.E. of Smyrna. The modern town, which consists of a collection of about fifty wretched huts, is built on the site of the ancient Telmessus, in the midst of a landscape of unrivalled beauty, although the town and neighbourhood are extremely unhealthy. There are still to be seen the remains of an ancient theatre in very good preservation, besides many tombs of various ages. The harbour, anciently called *Glaucus*, is very good, being sheltered from the sea by the island of Cavalière, and running into the land to the distance of 12 or 15 miles. It is at this place that travellers from Constantinople to Syria embark, and there is generally a great number of vessels in the bay. The trade of the town is extensive, and consists of wood, tar, honey, cattle, salt, and nuts, with many of which articles it supplies Rhodes. Provisions in this town are easily and cheaply procured.

This is also the name of a seaport in Rumili, 75 miles S.W. of Adrianople. The harbour is defended by a castle, and the town is the residence of a Greek bishop. It is the capital of a district, and its population is about 3000.

MALABAR. This tract of country extends along the western coast of India, from Cape Comorin to the River Chandragiri, in N. Lat. 12. 30. The British province of Malabar is a particular portion of this tract, which is situate between the 10th and 13th degrees of N. Lat. To the N. it is bounded by the province of Canara, to the S. by the rajah of Cochin's territories, to the W. by the ocean, and to the E. by the chain of the Western Ghauts, below which the country lies, extending about 200 miles along the sea-coast. The country may be divided into two portions, the first of which borders the sea-coast, and consists of a poor sandy soil, seldom above 3 miles wide, and in general not so much. Low branches of hills extend from the Ghauts to a considerable distance to the westward, and sometimes even to the sea. The strip of country bordering upon the sea is well adapted for the cultivation of rice; and it is remarkably intersected by inlets of the sea, which often run for great lengths parallel to the line of coast, receiving the various mountain streams, and communicating with the ocean by different narrow and shallow openings. In other places, the fresh water, as it descends from the mountains into the low lands within the downs upon the sea-coast, in the rainy season, totally overflows them, as the water has no issue, and must consequently stagnate until it evaporates. By this natural irrigation the lands are fitted for some particular qualities of rice. There are a few mountain streams and rivers; and the distance of the mountains from the sea is too inconsiderable for the formation of any large river. By far the most extensive portion of Malabar lies in the vicinity of the Ghaut Mountains, and consists of low hills, separated by narrow valleys, which are in general extremely fertile, being the receptacles of the fine particles of mould carried down from the hills. The hills are seldom of any considerable height, and have mostly level summits, which are bare in many parts, especially towards the N., and expose to the view large surfaces of naked rock, with remarkably steep sides. They are in general very industriously cultivated; their sides, which possess the best soil, being formed into terraces. The valleys are in most cases watered by rivulets which carry off the superfluous water, and where there is no issue, it overflows the adjacent lands. The upland is barren, and the cultivation much neglected; and it is in the valleys and extensive ravines, and upon the banks of the rivers, that the inhabitants chiefly reside. Dr Buchanan mentions in his *Journey from Madras*, &c., vol. ii., that some parts of the country which he passed through in this province were the most beautiful he had ever seen, being equal to the finest parts of Bengal, but the trees were loftier, and the palms more numerous. In many places the rice grounds are interspersed with high swells, that are crowded with houses; whilst the view to the N is bounded by naked rocky mountains, and to the S. by the lofty forests of the Travancore Hills. The climate is moist; the low country of Malabar, as well as the whole region which lies under the Western Ghauts, becomes excessively hot in the month of February; and the vapours and exhalations are so thick, that it is difficult to distinguish objects at the distance of even 5 miles. These vapours become visible around the mountains, where the cold is very severe. The moisture collected increases with the heat; and in March and April a prodigious quantity is accumulated, and floats in the atmosphere, sometimes ascending nearly to the tops of the mountains, where it is checked or condensed by the cold; but, descending immediately after, it is again rarified by the heat of the lower atmosphere into vapour, before it reaches the earth. At the setting in of the western monsoon, the whole is condensed into rain, which falls very heavily, partly in the low country, and partly in the mountains; and a small portion escapes and is blown across Mysore. These heavy rains serve to bear away the soil, and leave nothing but loose stones and sand upon the hills. The country abounds in lofty forests, which are sometimes intermixed with corn fields and plantations of fruit trees. The teak is produced in great abundance, mostly about Manarghaut; but it is too remote from any navigable river to be transported with a profit from the place of its growth. Sandalwood is also exported from Malabar, though it is not the produce of the country; at least such as is found within the limits of Malabar is not of a good quality, being entirely devoid of smell; but, growing as it does immediately to the eastward of the Western Ghauts, all that is produced towards the sources of the Cauvery naturally comes to Malabar, which affords the nearest ports that can be found for its exportation. The palm is produced in the greatest abundance about Palighaut, and, with proper care, an excellent spirit might be extracted from it. These forests, unlike others in India, were the private property of the land-holders, who exercised the right of selling and mortgaging the trees to Moplay merchants. The demand for teak timber was so great that the woods were fast becoming exhausted. With a view to the restoration of these forests, extensive tracts of waste land have been converted by the government into teak plantations. In the latter part of 1843, and the spring of the following year, no less than 50,000 young trees were planted in these nurseries. Cocoa-nut trees abound in the province. Black pepper is produced abundantly in Malabar, and forms the chief export by Europeans, who usually purchase about five-eighths of all that is produced, and carry it principally to Europe directly, or to Bombay and China. The remainder is chiefly exported by native traders to the Bay of Bengal, Surat, Cutch, Scinde, and other countries in the N.W. of India; and a considerable quantity finds its way to the Arabian ports of Muscat and Mocha, and to the British port of Aden. They use scarcely any horses or asses in Malabar; and such as are required for the use of the inhabitants are imported from the east. They have a small breed of cattle and buffaloes; but even these are but little used in the transportation of goods, which are usually carried by porters. Poultry have been introduced into the country by the Europeans; and common fowl may be had in abundance. Until a recent period slavery existed in Malabar; but in 1843 a legislative enactment was passed by the government, by the provisions of which slavery has been abolished throughout the whole extent of our eastern possessions. The country is distinguished by the neatness of its villages, which are superior to any in India, being built of mud, neatly smoothed, and either whitewashed or painted. Their picturesque effect is heightened by the beauty and elegant dresses of the Brahmin girls. The villages, as well as the bazaars, are the work of foreigners, the aboriginal natives of Malabar living in detached houses surrounded with gardens. The higher ranks use little clothing, but are remarkably clean in their persons; and all ranks are free from cutaneous distempers, excepting the very lowest castes.

The country being intersected by many rivers, and bounded by a high wall of mountains, was protected by these natural obstacles against the torrent of Mohammedan invasion which desolated other parts of India; and it was not till 1766, when it was invaded by Hyder Ali, that it was subjected to a foreign yoke. Hence the original manners and peculiar customs of the Hindus have been preserved here in much greater purity than in other parts of India. Besides the Hindus, who form the great proportion of the inhabitants, the population consists of Moplays or Mohammedans, Christians, and Jews. The Hindus are divided into the following castes, namely, Namburies or Brahmins; the Nairs of various denominations; the Teers, or Tiars, who are cultivators of the land, and freemen; the Malears, who are musicians and conjurors, and also freemen; and, lastly, the Patiars, who were slaves or bondmen. Of these castes, the most remarkable are the Nairs, the pure Sudras of Malabar, who all lay claim to be born soldiers, though they are of various ranks and professions. There are altogether eleven ranks of Nairs, who form the militia of Malabar, under the Brahmins and rajahs. They are proud and arrogant to their inferiors; and in former times a Nair was expected instantly to cut down a cultivator or fisherman who presumed to defile him by touching his person, or a Patiar who did not turn out of his road as a Nair passed. It is a remarkable custom amongst this class, that a Nair never cohabits with the person whom he calls his wife. He gives her all proper allowances of clothing and food; but she remains in her mother's or brother's house, and cohabits with any person or persons she chooses, of equal rank; so that no Nair knows his own father; and the children all belong to the mother, whose claim to them admits of no doubt. This state of manners also prevails in the neighbouring countries of Travancore, Bednore, and Canara.

As in Malabar the ancient Hindu state of property and manners prevails, almost the whole land, cultivated and uncultivated, belongs to individuals, and is held by a right which conveys a full and absolute property in the soil. There are many traditions and conjectures respecting the origin of landed property in those countries; and upon this subject a very full detail will be found in Mr Thackeray's report on the land tenures and assessments in Malabar, in the *Fifth Report of the Select Committee on India Affairs*, p. 799, in which he, along with Colonel Munro and others, strongly contends, that in the southern parts of India, namely, in Malabar, Tanjore, Trichinopoly, &c., the private right of property in the soil has been established from time immemorial. "The occupants of the land," says one of the collectors of the revenue in Southern India, "by whatever name distinguished, have the right of selling, bestowing, devising, and bequeathing their lands, in the manner which to them is most agreeable." The succession to property, in consequence of the extraordinary customs of the Nairs, depends on the mother, about whom there can be no mistake, though the father is frequently uncertain.

Christianity appears at a very early period to have made considerable progress on the Malabar coast; and there is a greater proportion of persons professing that religion in this than in any other part of India. Three ecclesiastical chiefs—two appointed by the Portuguese church at Goa, and one by the see of Rome—rule over this establishment, besides the Babylonish bishops who preside over the Nestorian community. At the time of Buchanan's visit 44 churches composed the Nestorian communion, which had been reduced from 200,000 souls, its amount before the arrival of Vasco de Gama, to about 40,000. The total number of Christians on the Malabar coast, including the Syrians or Nestorians, is computed to amount to 200,000, of whom 90,000 are settled in Travancore. The Jews are estimated at 30,000.

It is supposed that Malabar was, at a very early period, conquered by a king from above the Ghauts. The Nairs may have been established at the same time by the conqueror, or called in by the Brahmins, as a military body, to support the government. In process of time they obtained settlements in the land; and the chiefs, taking every opportunity to aggrandize themselves, became rajahs, and from a remote period continued to govern Malabar like independent princes until Hyder's invasion in 1760. Tradition, and the general opinion of the inhabitants, contradict the notion that any land-tax existed in Malabar prior to that event. No conclusive evidence is supplied on this subject by the doubtful analogies of the neighbouring states, in some of which, such as Travancore, no land-tax was said to exist, whilst in Canara a regular land-tax has been imposed for centuries. There does not seem to have been any urgent necessity for the establishment of a general land-tax, as there was no army besides the militia, nor indeed any expensive establishments. Hyder subdued the country in 1761, and expelled all the rajahs, except such as conciliated him by immediate submission. Disturbances were occasioned by these proceedings; but he succeeded in establishing his authority, and in 1782 appointed a deputy, who made still further progress in subduing and settling the country. In 1788 Tippoo, his son, proposed to the Hindus to embrace the true faith, and began by levying contributions on his infidel subjects, and forcibly circumcising many of the Brahmins, Nairs, and others. This produced a serious rebellion, which, however, was soon quelled by his vigorous administration; and in the meantime the country was laid waste by these tyrannical proceedings. On the breaking out of the war between Tippoo and the British in 1790, the refractory rajahs and Nairs, who were leading a predatory life in the jungles, were encouraged to join the Company's army. After the war, they were reinstated in their authority; but they made such large claims to independence, whilst they failed at the same time to fulfil their engagements for the payment of the revenue, and were also so tyrannical in their proceedings, that they were finally deprived of all authority, and allowed one-fifth of their revenues for the support of their dignity. Many of them, in consequence, had recourse to rebellion; but they were put down by a military force, and some of them punished. Since this period, under the management of the British collectors of revenue, the country exhibits comparative tranquillity, and is said to be advancing in prosperity. The population, according to the census which was taken in 1850, amounted to 1,514,909.

Under the name of Malabar is distinguished a large tract of country, extending along the western coast of India from Cape Comorin to the River Chandragiri, in N. Lat. 12. 30.; and the term is frequently erroneously applied to the whole country from Bombay to the southern extremity. The above account applies chiefly to the British province of that name. (E. T.)

MALABAR POINT, a promontory of Hindustan, on the S.W. extremity of the island of Bombay, remarkable for a cleft rock, in great repute for its sanctity amongst the numerous Hindus who resort thither for the purpose of being purified from their sins, which is effected by passing through the aperture, which is of considerable elevation, being situated amongst rocks of difficult access that in the stormy season are incessantly washed by the billows. In the vicinity are the ruins of a temple, said to have been blown up by the Portuguese; and a beautiful Brahmin village, built round a fine tank of considerable extent, with broad flights of steps down to the water.

MALACCA, an extensive region, situate in Southern India, consisting of a large peninsula, connected by the Isthmus of Kraw, about ninety-seven miles in breadth, with the province of Tenasserim to the N., whilst on all other sides it is bounded by the Eastern Ocean, having on the W. the Indian Ocean and the Straits of Malacca, which separate it from Sumatra, and on the E. the Gulf of Siam and the Sea of China. It extends from the 1st to the 12th degrees of N. Lat., and from the 98th to the 104th degrees of E. Long., and is 775 miles in length by 125 in average breadth. The country is a long, narrow strip of land, traversed by a chain of lofty mountains, and covered with extensive forests and marshes, so that it is very difficult to penetrate into the interior. A range of extremely bleak mountains, running through it from one extremity to the other, gives rise to innumerable streams, the courses of which, from the proximity of the mountains to the sea, are short, and they are obstructed at the mouths by bars and sandbanks, so that they cannot be ascended by vessels of any size. At the southern extremity of the continent are the islands of Bintang, Batang, and Singapore, with many others, so thickly clustered together, that they are only separated from the continent by narrow straits, and seem to be a prolongation of the land. On the W. coast also there are numerous islands, amongst which may be mentioned Pulo Pinang, or Prince of Wales Island.

The soil is not remarkable for its fertility, though, like other Malay countries, the coast is well covered with wood, and exhibits a great extent of verdure; but the teak tree has never yet been discovered in these forests. The fruits are excellent and plentiful; but grain is not produced in sufficient quantity, and is therefore imported from Bengal and Sumatra. The jungles, from their density and great luxuriance, are impervious to animals, and game is in consequence scarce. From the rivers, as well as the sea, the inhabitants derive a plentiful supply of fish.

The political state of Malacca has been subject to many revolutions, having been occasionally dependent on Siam when that monarchy was in the height of its power, and when its supremacy was owned by the whole peninsula. But since the Siamese have yielded to the increasing power of the Burmans, all the southern portion of the peninsula has shaken off the yoke, and the northern states pay only a moderate tribute. The whole of the sea-coast, from that latitude to Point Romania, is still possessed by the Malays, who are mixed in some places with the Buggesses from Celebes, and who have still a small settlement at Salengore. The northern and inland parts of the peninsula are inhabited by the Patany people, who appear to be a mixture of Siamese and Malays, and who inhabit independent villages. The Negro race is found in the interior amongst the aboriginal natives. The great majority of the inhabitants are, however, of the Malay race, who are well known and widely diffused amongst all the eastern islands. The origin of this remarkable race is not very distinctly known. They are understood, however, not to be natives of this country, but to have come originally from the district of Palembang, in the interior of Sumatra, situate on the banks of the River Malaya. Having crossed over about the end of the twelfth century to the opposite continent, they, in 1252, founded the city of Malacca. They are of a daring, restless, and intrepid disposition; their character forming in this respect a striking contrast to that of the timid inhabitants of Hindustan. They are brave in war, but ferocious and vindictive, merciless to enemies and strangers, and capricious and passionate even to friends. They are proud and irascible, carrying the point of honour to excess, with a quick sensibility to the slightest insult, which drives them to a degree of fury bordering on desperation; and it is by a series of what they, in their overwrought fancies, consider to be insults, that they are excited to a state of frenzy which ends in that act of wild atrocity known by the name of "running amok," from the word *amok*, signifying kill, kill. The Malay, when he has resolved on this desperate step, proceeds still farther to inflame his passions by taking a dose of opium, when he throws loose his black hair, and drawing his deadly crease, rushes into the streets, thirsting for vengeance, and crying "kill, kill," slays every one whom he meets in this furious mood. But it has been found that these unruly passions, which often broke out into violent excesses under the tyrannies of their Dutch rulers, were greatly allayed by kind treatment; and that the Malay, in these circumstances, was transformed into an entirely different character, displaying gratitude, affection, fidelity, and higher sentiments of honour than are found amongst any other class of natives in India. Those Europeans who have engaged them as servants, and who have treated them well, inform us that they found them faithful and attached domestics. The free Malays are an intelligent, active, industrious body of men, engaged, like the Chinese, in foreign trade. They have always addicted themselves to seafaring pursuits, and to piracy, which they follow as if it were a lawful trade; and hence they are the terror of the effeminate Asiatics. Their prows are many of them fine vessels, and navigated with skill; but the Malay, though in general a bold and hardy mariner, is apt to sink under a continuance of cold or bad weather, even sooner than the feeble but more docile lascar of Bengal. Though they have been more circumscribed in their piracies by the maritime superiority of the Europeans in the eastern seas, and no longer retain those daring habits which rendered them the scourge of the peaceful trader, they still carry on petty depredations; and trading vessels are sometimes cut off, and their crews murdered with every circumstance of atrocity.

The government of the Malays is a rude description of monarchy, with a turbulent aristocracy, or something like the principles of the feudal system. The head of the government is a rajah or sultan, a name assumed from the Arabians; and under him a certain number of nobles, with their train of vassals. But in practice there is no regular system of subordination, the sultan trampling on the chiefs and the people, and they again rebelling against his authority; so that there is little else amongst them but violence and disorder, which contribute to nourish their ferocious habits.

The language of the Malays has obtained very general currency in several states upon the continent, as well as amongst the eastern islands, though it has gained no footing in the interior of Hindustan. On the sea-coast, and at the mouths and on the banks of navigable rivers, it is the medium of commercial and foreign intercourse; and the currency which it has acquired may be ascribed partly to the commercial and enterprising character of the people, who, by their mercantile habits, or the power of their arms, have established themselves in every part of the archipelago, and also to its own valuable qualities of simplicity in the structure, and even of pronunciation. In writing it, they use the Arabic character, with the addition of six other letters. The Malays have few books in their language, and these consist chiefly of transcripts and versions of the Koran, commentaries on the Mohammedan law, and tales in prose and verse, many of them translations of the popular tales current in Arabia, Persia, India, and the neighbouring island of Java. They have also some historical compositions.

The Malayans profess the Mohammedan religion. Until the year 1276 they were pagans, or followed some corrupted form of Hindu idolatry. Sultan Mahommed Shah, who ascended the throne in the thirteenth century, was the first prince who, by the propagation of this faith, acquired great celebrity during his long reign of fifty-seven years. His dominion extended over the neighbouring islands of Lingen and Bintang, together with Johore, Patany, Quedah, and Pera, on the coasts of the peninsula, besides several districts in Sumatra, all of which acquired the appellation of Malaya. During part of the fifteenth century, Malacca was under the Siamese sovereigns. In 1509 Sultan Mahmud repelled the aggression of the King of Siam; but in 1511 he was conquered by the Portuguese under Albuquerque.

MALACCA is the capital of the country of Malacca, and is situate on the straits of the same name, near the southern extremity of the Malay Peninsula. The town is large; many of the houses are built of stone; and there are several spacious and handsome streets. But that part of it inhabited by the natives consists of bamboo and mat huts. Since the formation of the British settlement at Pulo Pinang, or Prince of Wales Island, its commercial importance has declined. The surrounding country is fertile and beautiful, being finely diversified for eight miles round with hill and dale; and beyond that distance it is rendered impracticable by woods and morasses. There is a good roadstead for large ships about a mile and a half from the place; but the entrance to the river is rendered intricate by a bar, over which boats cannot pass before quarter flood, nor after last quarter ebb, without much difficulty. Under the lee of the island, near to the fort, there is a harbour, where, in the south-west monsoon, vessels of light burden may be secured. On the southern side of the river is a fort, the walls of which are in a ruinous condition. The chief imports are grain, which is brought in considerable quantities from Bengal, Java, and Sumatra, opium, piece-goods, silks, and dollars. The exports are chiefly tin, pepper, sago, canes, elephants' teeth, biche-de-mer, and some gold dust. Fruits and vegetables are abundant; and there is also plenty of buffaloes, hogs, poultry, and fish, at moderate prices, though sheep and bullocks are scarce. Malacca was founded about the year 1252; and in 1508 it was first visited by the Portuguese, who, on a quarrel which broke out, were arrested by the king, and being thrown into prison, several of them were put to death. Albuquerque, the renowned Portuguese commander, immediately declared war against this eastern prince; and, after an obstinate contest, stormed the town of Malacca, which became one of their principal settlements, and the key of their trade with the seas beyond India. In 1605 it was attacked by the Dutch, who destroyed a Portuguese fleet in the roads, but failed to take the place. In 1640, however, they reduced it after an obstinate resistance, and retained it till the year 1795, when it was subjected by a British force, but was restored at the peace of Amiens. It was afterwards recaptured by the British, but once more restored to the Dutch in 1818, after the general pacification. In 1824 the town, and a district containing an area of about 1000 square miles, were finally transferred to the British among the cessions made by the King of the Netherlands, in exchange for the British possessions on the island of Sumatra. E. Long. 100., N. Lat. 5. (E. T.)

MALACHI, the last of the minor prophets, flourished contemporarily with Nehemiah; and from various coincidences in his prophecy with Nehemiah chap. xiii., it may be concluded that they acted together in the work of political and religious restoration. His name (*My Angel*, or rather *Angel of Jehovah*) has by some been regarded as only an official title, and, in absence of evidence in regard to his personal history, Ezra, Nehemiah, Mordecai, and even an incarnate angel, have been put forward as authors of the book. In the same way, all Scripture history might be unsettled. That Malachi flourished later than Zechariah is sufficiently evident from the fact that he is not mentioned along with that prophet in the book of Ezra; and from internal evidence it is plain that he lived to see a more thorough restoration of the Jewish worship than Zechariah was privileged to see. He even lived to see the restored worship decline; and amid the decay of morals he prophesied the advent of the forerunner of the Messiah. The canonicity of this book is undoubted. Special expositions of it have been written,—among others, by Venema, Bahrdt, Faber, and Fischer.

MALAGA, the third seaport of Spain, and capital of the province of the same name in Granada, is situate on the Mediterranean, in 36. 43. N. Lat., 4. 26. W. Long., 65 miles E.N.E. of Gibraltar, and 253 S. by W. of Madrid, at the extremity of a fine large bay, and on a plain bounded by lofty hills on the N.E. and N.W. In the clearness of its sky, which a cloud rarely obscures, and the beauty of its bay, it resembles Naples, to which it has sometimes been compared. The scanty river Guadalmedina flows here into the sea after receiving the Guadalhora; and the town lies principally on the left bank of the former; the districts of La Trinidad and Perchel, on the latter, being little more than a suburb. Sheltered on the E. and W., the climate is very salubrious. There are no endemic diseases, although, like other Mediterranean seaports, it has suffered much at various times from yellow fever, &c. The streets near the sea are spacious and comparatively modern, giving the town a fine appearance from the bay; the other streets are narrow and ancient, still remaining almost as they were when the town was taken from the Moors in 1487. There are various *plazas* and *paseos*. In the Plaza de Riego was erected, in 1842, a monument to the unfortunate Torrijos. The edifices most worthy of note are,—the cathedral, the custom-house, and the bishop's palace. The cathedral was commenced by Diego de Siloe, architect of that of Granada, in 1526, in the Greco-Roman style, which he introduced, and was continued by various architects till its completion in 1782 by Jose Bada. It exhibits, in consequence, a singular mixture of styles; but the general effect of the interior is pleasing, and the exterior would be imposing were it not marred by the crowd of shabby houses about it. The custom-house is a stately and spacious edifice, built partly on the site of the Moorish fortress Alcazaba, to the N.E. of the town. It was begun in 1791, but the work being interrupted by the war, was not finished till 1829. The bishop's palace, which contains also the offices, archives, and library of the see, was erected in 1772, at the expense of the then prelate, Don José Franquis. Of more ancient buildings, the two Moorish fortresses, Gibralfaro and Alcazaba, on a hill to the N.E., deserve mention. The former, which is extensive, and still in good preservation, was built A.D. 787, by Abdelrhaman I., King of Cordova, on the site of a more ancient tower, and offered an obstinate resistance to the Catholic kings. Of Alcazaba the remains are trifling. On the whole, Malaga, though not a handsome town, has a more modern aspect than most Spanish towns. An object of special attraction to visitors is the English burying-ground, situate about a mile from the city, to the E. of the Alcazaba, beautifully laid out, and at much expense; the soil being terraced, irrigated, and planted with cypresses. To complete the description of the port, it must be added, that though there is no regular harbour, vessels receive shelter from a mole about 884 yards in length, at the extremity of which is a lighthouse with a rotatory light, standing about 130 feet above the sea-level. To prevent the silting up of the harbour so formed, two smaller lateral breakwaters were subsequently formed. The commencement of the former work dates from 1588; but it did not reach its present length before the end of last century. The harbour is capable of containing several hundred merchant vessels; and ships of the largest burden can approach the quays.

The commerce of Malaga consists chiefly in the productions of the province, the staple being wine and raisins. The latter are made from the June harvest, and largely exported. The quality has of late years much improved, and they boast that their raisins quite equal those of Valencia. There is a second and third harvest, producing wines exported chiefly to the United States and South America. "Formerly vast quantities of very inferior quality were manufactured, but were found unsaleable even to the Americans; they have therefore been obliged to change the system, and the whole class is much improved in consequence." (*Widdrington.*) The Muscatel, Lachryma Christi, and Vino de Guindas (so called from its being flavoured with cherries), are the best wines. The *lagrimas* is made from the droppings of the large white Muscatel grapes unpressed. The vineyards around Malaga are estimated to produce annually, of all sorts—sweet, dry, and luscious—between 30,000 and 40,000 butts, of which nearly 27,000 are exported. Olive oil, saffron, soap, and some other articles, are also exported. The most active period in the port is from the 15th of August to the end of October, the exportation of the new fruits going on. This period is called the *Bendejà*. The harbour is then filled with vessels of all sizes and flags, and the streets choked with cars and wagons bringing in the produce of the fields. Besides the vines and cereals, the province boasts many tropical products: the sugar-cane, called *indigenous*, is grown along the E. coast from Torrox to Velez Malaga; the Malaga yam or batata, oranges, lemons, figs, &c., are cultivated. Silk is reared, and cochineal to some extent, though the exposure to the N.W. winds is not favourable to the necessary plantation of cactus. Were the land not so heavily burdened, and were a better system of agriculture adopted, this province would be rendered infinitely more productive. Sheep, hogs, and goats, are reared in the mountainous ranges. The horses are not so good as those of Lower Andalusia. Formerly, in the oak woods around Malaga, a vast quantity of hogs were reared, and bacon exported; but these woods have given place to the vine, olive, &c., which clothe the hills to their summits. There is abundance of small game, hares, rabbits, partridges, and quails, in their season.

There are in the town, manufactories of soap, leather, and linen cloths; but by far the most important and remarkable are the iron foundries, particularly that called La Constancia, which took its rise, in 1826, from the discovery of the abundant mines of Sierra Blanca, near Marbella. A company was formed, and workmen brought from Biscay, Piedmont, Belgium, and France; but after numerous and costly endeavours, it was found that the result did not cover the outlay, and the works were on the point of being abandoned, when one of the directors, Don Manuel Heredia, took the whole management and burden upon himself, introduced the English method of smelting the iron with coal, and brought over a number of English workmen. The iron is made at Marbella, and brought to Malaga to be refined. There are two foundries in Malaga for this purpose: the tall chimney of one is a conspicuous object from the bay. Including the Marbella works, there are about 3000 operatives employed in this manufacture. The mines are very productive, and might supply all Spain with iron. There are, besides, in the province eighteen mines of lead and some of graphite. In Las Chapas, district of Ogen, argentiferous lead ore has been discovered, but in too small quantities. Copper and nickel are also found. There are quarries of marble and various other stones, among which the famous stone of Mijas, a kind of opaque agate. There is an annual fair in Malaga, commencing on the 8th of September, and lasting eight days, held in the Alameda (shaded walk) de Olletas. It is not much frequented.

Malaga is the *Malaka* of Strabo, a word which has been variously derived. By some, through the Phœnician, it is referred to the quantities of salted fish for which it was celebrated. Wilh. Humboldt says it is of Basque origin, meaning the slope of a hill. At all events, the foundation of the town is universally attributed to the Phœnicians. From the Carthaginians, in whose hands its commerce flourished, it was wrested by the Romans, who conferred on it the title of *Civitas Federata*. The Roman remains found in the city and environs are innumerable. (*Ponz. Viage.*) It was taken possession of by the Arabs, without opposition, after the disastrous battle of Guadalcte, and is mentioned as one of the most important cities of Andalusia in the division made of Spain by Jusuf, in 747. It was attached to the caliphate of Cordoba; but on the fall of this caliphate with the dynasty of Omia in 1015, it became the seat of an independent kingdom, with various fortune. In 1487 it was wrested from the Moors by Ferdinand and Isabella, after undergoing all the horrors of a protracted siege. In 1810 the city suffered much from the French general Sebastiani having offered an ineffectual resistance. In 1834 it was the theatre of a melancholy tragedy. General Torrijos and forty-nine Liberals suffered military execution on the 11th of December in that year. A monument has since been erected to their memory. The population of Malaga in 1847 amounted to 68,577.

MALAGRIDA, Gabriel, an Italian Jesuit, was born in 1689. Having entered the Order of Jesus, he was despatched by that fraternity to Lisbon. There, in process of time, he raised himself to notoriety by his pretensions to sanctity and supernatural intercourse with heaven. Yet this very prominence subjected him to a greater amount of the suspicion with which the government of Portugal at that period regarded the Jesuits. Accordingly, in 1758, Malagrida was apprehended on the charge of being privy to a conspiracy against the crown. Instead of being arraigned before a civil tribunal, he was delivered into the power of the Inquisition. Accused before that court of having written two books relating his interviews with the Virgin Mary and her mother St Anne, Malagrida was condemned as a heretic, and was burnt at the stake in September 1761.

MALAR, a lake of Sweden, stretching westward from the Baltic, and lying between the laens of Westeras, Upsala, Nyköping, and Stockholm. Unlike most other lakes, it is made up of a number of smaller lakes united by channels, so that, although its length is about 78 miles, and its average breadth 12, there is scarcely throughout this whole extent a sheet of water of a mile square. It is studded with islands to the number of about 1300; and it sends a great many branches into the land, all of which are navigable. The level of the water is nearly the same as that of the Baltic, and numerous steamers ply upon it to and from Stockholm, which is situate at the eastern extremity on both sides of the lake. The convenience of such a sheet of water for navigation is very great, and its advantages have been further increased by the Södertelge and Strömsholms canals. The former of these is about two miles long, and opens up the communication with the Baltic; while the latter extends from the western end of the lake, for 50 miles into the interior, in a northerly direction, and terminates in the region of the mines in the Lake of Barken. The scenery of the banks is very beautiful, and there are many villas and country seats belonging to the inhabitants of Stockholm.

MALAY PENINSULA. See Malacca.

MALCOLM, Sir John, G.C.B., the son of a farmer, was born in May 1769, in the parish of Westerkirk in Dumfriesshire. At the age of twelve he received a cadetship in the Indian army; and in April 1783 landed at Madras, and joined his regiment at Vellore. For some time he was noted among his comrades for little else than a youthful light-heartedness, which gained for him the epithet of the "Boy Malcolm." But when a war with Tippoo Saib broke out in 1790, Malcolm, ambitious of obtaining a diplomatic office, began to improve his imperfect education by the study of the languages, especially Persian. Accordingly, in 1792, when stationed before Seringapatam, he was appointed to the staff in the capacity of Persian interpreter. Forced by ill health to leave for England in 1794, he employed his leisure in cultivating those literary talents which contributed in no small degree to his subsequent eminence. On his return to India in 1796, Malcolm became secretary to Sir Alured Clarke, commander-in-chief at Madras, and afterwards to his successor, General Harris. In 1798 his knowledge of the languages and political state of India induced Lord Wellesley, the governor-general, to appoint him assistant to the resident at Hyderabad. The duties of this office he was soon summoned to discharge by the rising of a mutinous spirit among the French troops in the pay of the Nizam. Displaying great coolness and decision, he surrounded the malcontents with a body of 1500 horse, and, without firing a shot, forced them to lay down their arms and disperse. In 1799, beneath the walls of Seringapatam, began his intimacy with Arthur Wellesley, which in a short time ripened into a lasting friendship. During the same year he acted as secretary to the commission appointed to settle the Mysore government. About this period Lord Wellesley held the current opinion that Bonaparte's movements in Egypt and Palestine tended towards an invasion of the British possessions in India. Accordingly, he despatched Malcolm on an embassy to Persia for the purpose of forming an alliance with that country. Arriving at Teheran in December 1800, Malcolm so influenced the Persian courtiers by his liberality and imposing address, that a treaty was struck, in which Persia agreed to repel the French should they ever attempt to enter her boundaries. At the close of the Mahratta war in 1804, when General Arthur Wellesley had succeeded, by a rapid succession of brilliant victories, in restoring the peishwa to his ancient supremacy, Malcolm was employed in negotiating with the conquered enemy. In 1807 and 1810 respectively, he was once more sent as ambassador to Persia; but beyond the information which he afterwards incorporated in his history of that country, his missions were attended with no substantial result. Malcolm sailed for England in 1811, and shortly after his arrival in 1812 he received the honour of knighthood. His interval of leisure he devoted to the composition of the *History of Persia*, a work which was published in 1815 in 2 vols. 4to. No sooner had he returned to India in 1817, than he was nominated the governor-general's political agent, and brigadier-general under Sir T. Hislop. In this latter capacity he served against the Mahrattas and the Pindarees, and bore so distinguished a part in the victory of Mehidpoor, that he shared in the thanks that were awarded to his commander by the British Parliament. With no less success did he attempt to introduce peace and prosperity into the district of Malwah, of which he had been appointed governor. In 1821 Sir John Malcolm returned once more to England; but on being appointed in 1827 governor of Bombay, he repaired again to India. The influence of this new office was directed to the promotion of cotton and silk cultivation, and to the establishment of steam communication with England. He left India for the last time in 1830; and shortly after his arrival in England became M.P. for Launceston. He died of paralysis in May 1833. Besides the work mentioned above, Sir John Malcolm wrote,—*Sketch of the Political History of India since the Introduction of Mr Pitt's Bill in* 1784 *to the present date*, 8vo, London, 1811; *Sketch of the Sikhs*, 8vo, 1812; *Observations on the Disturbances in the Madras Army*, 8vo, 1812; *Persia, a Poem*, 8vo, 1814; and a posthumous work, *Life of Lord Clive*, 1836. *The Life and Correspondence of Major-General Sir John Malcolm, G.C.B.*, was published by John W. Kaye, 2 vols. 8vo, London, 1856.

MALCZEWSKI, Antoni, an eminent Polish poet, was born about 1792 in Volhynia. At the age of nineteen he entered the Polish army, and was afterwards in the suite of the Emperor Alexander I. until 1816, when, owing to a duel which he had fought, he was forced to quit the service. After travelling for the next five years in Switzerland, Italy, and France, he settled in the Ukraine as a farmer, and devoted his leisure hours to poetry. Compelled, however, by the voice of scandal to leave that district, he removed with a diminished fortune to Moscow. He died there in great poverty in 1826. Malczewski's principal poem, *Maria, a Tale of the Ukraine*, was published at Warsaw shortly before his death. It was printed in the original in London in 1836.

MALDA, a town of Hindustan, in the lieutenant-governorship of Bengal, situate on a river which communicates with the Ganges. The manufactures which were formerly carried on in this town have disappeared before the superior cheapness of those brought from the United Kingdom, and the place has in consequence greatly deteriorated. The district to which this place gives its name is bounded on the N. by Purneah, on the E. by Dinajepore, on the S. by Rajeshahye, and on the W. by Moorshedabad. It has an area of 1000 square miles, and a population of upwards of 400,000. The town of Malda is in E. Long. 88. 11., N. Lat. 25. 3.

MALDIVE, or MALEDIVA ISLANDS, a remarkable group of islands in the Indian Ocean, extending almost in a straight line between Lat. 7. 6. N. and 0. 40. S., Long. 72 48. and 73. 48. E.; 466 geographical miles in length, and 46 or 48 miles in breadth. These islands lie in circular groups or *atolls*, formed by coral reefs, and divided from each other by channels of great depth. The water inside the atolls is generally shallow and calm, though on the surrounding reefs the waves beat with considerable violence. The reefs are not unbroken, and there are many openings which permit the entrance of ships; while the depth within is in most cases sufficient to allow them to cross from one part to another. Four safe channels through the Maldives have been explored by European vessels, and there are other two which are believed to be safe, but which have not as yet been explored. The number of the atolls is 17, and the islands, which are situate for the most part on the coral reefs, are reckoned by the natives to be 12,000 in number, but are believed to amount in reality to three or four times as many. The name is believed to be derived from two words in the Malabar language signifying a thousand islands, from their great number. The atolls are generally circular or oval in their shape, and their circumference is on an average 90 miles. The largest island is Mali, N. Lat. 4. 10., E. Long. 73. 40. It is about 7 miles in circumference, and has a population of about 1500 or 2000. The islands are all of a circular form, and are characterized by a lagoon or lake in the centre, which is found even in the smallest of them.

The soil is sandy, mixed with vegetable remains; and at the depth of about 3 feet a layer of sandstone occurs. All the islands of any size are richly clothed with palms, fig trees, bread-fruit trees, &c., and they are all covered with a thick jungle. On some of them there are plantations of Indian corn and sugar-canes, and a small quantity of cotton is grown, together with millet; but as the soil is not adapted to the growth of rice and wheat, these grains are imported. The food of the inhabitants consists chiefly of fish and cocoa-nuts. A small number of cattle are kept on some of the islands of the largest atolls; but there are no sheep or goats. Notwithstanding their tropical situation, the climate of these islands is not remarkable for great heat; the nights are cool, and the plentiful dews prevent the temperature from exceeding a moderate degree of heat. The inhabitants have attained to some degree of civilization, and carry on a considerable amount of commerce among themselves and with the mainland of India. The different islands have each a peculiar trade of their own, and the communication is kept up by means of boats. The commerce with India is also carried on chiefly by native boats, for though Indian vessels used formerly to frequent these islands, the navigation was found to be so difficult and dangerous, that this practice has been discontinued. The principal articles of export are cocoa-nuts and cowries, together with quantities of salt fish; while grain, cotton, silk, tobacco, and various other European goods are imported. The inhabitants are quiet and inoffensive, and little accustomed to war. They are strict Mussulmans; but, contrary to the usual practice in such countries, the women are not kept in seclusion. The people are governed by a monarch, who is styled Sultan of the Thirteen Atolls and Twelve Thousand Isles, but who acknowledges his dependence on the British government of Ceylon, to which he annually sends tribute. Pop. of the whole group, from 150,000 to 200,000.

MALDON, a municipal and parliamentary borough and market-town, county of Essex, on the right bank of the Chelmer, about a mile from its junction with the Blackwater, 37 miles N.E. by E. of London by road, and 44 miles by the Eastern Counties Railway. It consists of two principal streets, crossing each other at right angles, the largest of which runs from E. to W., and is upwards of a mile in length. The town is only partially paved, but is well lighted with gas, and excellently supplied with water. The buildings are mostly of ancient date, but many handsome structures may be seen of recent erection. Among the public buildings the chief is All Saints Church, a very ancient edifice. There is also an ancient town-hall, supposed to have been built in the time of Henry VI. The town possesses also a free grammar school with a library, which was founded by Alderman Breeder in 1608, besides minor educational and several charitable institutions. The harbour, which is formed by the River Blackwater, is accessible to vessels of 200 tons burden, while those of a larger size are loaded by means of lighters in the offing. The town drives a thriving trade in salt, coal, iron, corn, &c. There is also a good deal of fishing, and fine oysters are got in great abundance here. There are in the town malt-houses, breweries, boat-building yards, sail-lofts, cooperages, soap-works, and iron foundries. The market-day is Thursday; and fairs are held twice a year, in May and September. The borough is governed by four aldermen and twelve councillors, and sends two members to Parliament. This town is supposed to be the ancient *Camulodunum*, from which its modern name seems to have been derived. It was the earliest colony established by the Romans in Britain, and had formerly been the seat of some native princes. Pop. (1851) 5888.

MALDONADO, a seaport-town of Uruguay, South America, on the N.E. shore of the estuary of the Rio de la Plata, 72 miles E. of Monte Video, S. Lat. 34. 53. 30., W. Long. 54. 57. 48. The town is situate about 2 miles from the sea, on an elevation rising to the height of 250 feet, and consists chiefly of brick houses thatched with straw. There is a large square in the centre, occupied by the principal buildings, among which is a new church. A considerable amount of trade in cattle and hides is carried on here; and the harbour, which is separated from the town by a ridge of sandy hillocks, is protected by the island of Gorriti. The surrounding country is an open plain, slightly undulating, and affording excellent pasturage for horses and cattle. Pop. about 1500.

MALEBRANCHE, NICOLAS, a distinguished philosopher of France, was the son of Nicolas Malebranche, secretary to the French king, and Catherine de Lauzon, sister to the viceroy of Canada, and was born at Paris on the 6th August 1638. Of an extremely feeble constitution and deformed habit of body, he received his elementary education from a domestic tutor, and only left the parental roof when sufficiently advanced to enter upon a course of philosophy at the college of La Marche, and subsequently to study theology at the Sorbonne. He resolved to enter the church; and his retiring and studious disposition having

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induced him to decline the offer of a canonicate in Notre Dame, he, in 1660, entered the famous Congregation of the Oratoire. Up to the age of twenty-six, Malebranche applied himself painfully to the study of ecclesiastical history and biblical criticism; but as he had no taste for such investigations, his efforts met with little success. Having accidentally fallen upon the *Traitê de l'Homme* of Descartes, Malebranche became alive to his true vocation. He was so overpowered by the novelty and luminousness of the ideas, and by the solidity and coherence of the principles of that admirable work, that he was repeatedly compelled, from violent palpitations of the heart, to desist from reading it. Malebranche was from that hour consecrated to philosophy; and after ten years' profound study of the works of Descartes, he produced his celebrated *Recherche de la Vérité*. This work has for its object an inquiry into the faculties of the human understanding, thereby to determine articulate rules for the avoidance of error and the advancement of truth. It contains the germs of all the metaphysical theories developed in Malebranche's subsequent publications, and especially in his *Metaphysical and Christian Meditations*, and his *Discourses on Metaphysics and Religion*. All his works are characterized by originality of conception, elevation of doctrine, and beauty of style; and on their first appearance they met with an extraordinary degree of success. As a writer, Malebranche is placed by the ablest critics side by side with Fénélon; and, singular to say, while vehemently declaiming against the imagination and the study of poetry, there is no writer who has employed that noble faculty with such charming success in giving a grandeur and a glow to the subtlest metaphysical disquisitions, and in lending an attractiveness to the coldest abstractions of the reason. His dialogue between the creature and the Creator, in his *Meditations*, reaches the highest pitch of eloquence and inspiration. Malebranche was less successful in polemics than in pure speculation and in the free expression of his doctrines. He liked better to dogmatize than to discuss; yet after the publication of the *Recherche de la Vérité*, he was dragged, in spite of himself, into a perfect whirlpool of polemics. Like the majority of the great philosophers of the seventeenth century, Malebranche was a mathematician and a natural philosopher; and he was in 1699 chosen an honorary member of the Academy of Sciences. His society was universally courted, and few foreigners of any pretensions to learning neglected, when in Paris, to visit the eloquent philosopher, who had, by his hypothesis of *seeing all things in God*, offered such an ingenious solution of the harassing problem of external perception. His health, never robust, became daily weaker, until he was at last reduced to a skeleton. He died on the 13th of October 1715, "a tranquil spectator," says Fontenelle, "of this long death." (For a full and detailed critical exposition of the philosophy of Malebranche, see the First *Preliminary Dissertation* to the present work, p. 74, *et seq.*)

The following is a list of Malebranche's works:—*Recherche de la Vérité*, 12mo, Paris, 1674. Six successive editions of this work received the author's corrections and additions, and it was translated into Latin, English, and modern Greek. *Conversations Métaphysiques et Chrétiennes*, 12mo, Paris, 1677; *Traité de la Nature et de la Grace*, Amst., 12mo, 1680; *Meditations Métaphysiques et Chrétiennes*, 12mo, Cologne, 1683; *Traité de Morale*, 12mo, 1684; *Entretiens sur la Metaphysique et sur la Religion*, 12mo, 1688; *Traité sur l'Amour de Dieu*, 12mo, 1697; *Entretiens d'un Philosophe Chrétien et d'un Philosophe Chinois*, 1708; *Réponses de Malebranche à Arnauld*, 4 vols. 12mo, 1709; *Rèflexions sur la Prémotion Physique*, 12mo, 1715. (See *L'Eloge de Malebranche*, by Fontenelle; *Dictionnaire des Sciences Philosophiques*; and the *Biographie Universelle*.)

MALESHERBES, Chretien Guillaume de Lamoignon de, minister and last counsel to Louis XVI., was born at Paris on the 6th of December 1721. He was descended of an illustrious family, which had occupied the highest offices in the magistracy, being son of the chancellor of France, William de Lamoignon, and grandson of the celebrated advocate-general Lamoignon. His early education he received at the Jesuits' College, and afterwards applied himself with great assiduity to the study of law, history, and political economy. He was chosen a counsellor of the parliament of Paris at the age of twenty-four, and succeeded his father as president of the Court of Aids in the year 1750, and received the superintendence of the press, which, in his hands, became the means of promoting liberty to a degree beyond all former example in that country. Through his favour, the *Encyclopédie*, the works of Rousseau, and many other free speculations, issued from the press, in defiance of the terrific anathemas of the Sorbonne. The superintendence of the press having been taken from him, and conferred upon Maupeou, he was only the more intent on fulfilling the duties of his presidentship, and opposing arbitrary power. Having presented a remonstrance to the king, containing a free protest against the enormous abuses of *lettres de cachet*, he was banished to his country seat by a *lettre de cachet*, and the Duc de Richelieu, at the head of an armed force, abolished the tribunal. On the accession of Louis XVI. to the throne in 1774, he was chosen minister of state. In this elevated station he was only ambitious to extend the sphere of his usefulness. His first care was to restore to liberty the innocent victims of the former reign, and to encourage commerce and agriculture—endeavours in which he was supported by Turgot, comptroller-general of the revenue. He resigned his office in the month of May 1776. He then set out upon a journey through France, Switzerland, and Holland, and after an absence of some years, he returned to his favourite mansion, fraught with such a stock of valuable knowledge as his age and experience qualified him to appreciate. When, by a decree of the National Convention, Louis was to be tried for his life, Malesherbes, nobly forgetting the manner in which he had been banished from his councils, generously offered to plead his cause. He was the person who announced to the unfortunate monarch his cruel fate, and one of the last who took leave of him when taken out to suffer. In the first days of December 1793, three members of a revolutionary committee of Paris came to his country seat to arrest his eldest daughter and his son-in-law M. de Rosambo, and next day new emissaries appeared, and carried him off with his children. The tribunal of blood would scarcely deign to hear him who had been so long the oracle of justice, and by whom so many victims had been saved from death. Malesherbes heard his sentence without emotion, and marched to death with undisturbed serenity. He perished by the guillotine, with his whole family, at the age of seventy-two, on the 22d of April 1794.

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Grave errors may be laid to the charge of Malesherbes, but all of these had their source in that love of good which in him was as much a passion as a principle. Malesherbes left a number of MSS. which were dispersed by the vandalism of the Revolution, particularly *Observations sur le Méléze, sur le Bois de Sainte Lucie, sur les Pins, sur les Orchis; Mémoire sur les Moyens d'Accélerer les Progrès de l'Economie Rurale en France; Idées d'un Agriculteur, &c.; Mémoire pour Louis XVI.; Observations sur l'Histoire Naturelle de Buffon et Daubenton; Mémoires sur la Librairie et la Liberté de la Presse; Introduction à la Botanique;* three letters in the *Journal des Savants* on the geological phenomena of the environs of Malesherbes. Under the title of *Œuvres Choisies* have been printed (Paris, 1809) extracts from his most celebrated remonstrances; and we have also *Pensées et*

Maximes de M. de Malesherbes suivies de Réflexions sur les Lettres de Cachet, 1802, in 12mo.

MALHERBE, François de, a celebrated French poet, descended of a noble and ancient family, was born at Caen in 1555. He completed his studies at Heidelberg and Basle; and having quitted Normandy at the age of seventeen, he went into Provence, where he attached himself to the family of Henri d'Angoulême, the natural son of Henri II., and was in the service of that prince till he was killed by Altoviti in 1586. After having served in the wars of the League he returned to Paris, and wrote an ode on the arrival of Marie de' Medici, which established his poetical reputation. At length, Cardinal du Perron being informed of his merit and abilities, introduced him to Henri IV., who took him into his service. After the death of that monarch, his widow, Marie de' Medici, settled a pension of 500 crowns upon our poet, who died at Paris in 1628. Malherbe so far excelled all the French poets who preceded him, that Boileau considers him as the father of French poetry. He had a delicate ear, a very refined taste, and was singularly scrupulous in the choice of his expressions. His poetry is remarkable for graceful and elegant versification, but is deficient in reach of thought and power of imagination. (See *Œuvres de Malherbe*, 1 vol. 4to, Paris, 1797; also *Vie de Malherbe*, by Racan.)

MALLET, David, the author of the ballad of *William and Margaret*, was the son of a small innkeeper at Crieff, in Perthshire, and was born about the year 1700. His real name was Malloch, and he is supposed to have been a descendant of the proscribed clan of Macgregor. According to the most recent account, he studied first at Aberdeen, and afterwards at Edinburgh, and while attending the university in the latter city he became tutor to the sons of the Duke of Montrose. Accompanying his pupils to London, and on a tour through the Continent, and coming in contact with persons of the highest rank, Mallet gradually acquired that knowledge of the world, and that refinement of manners, which were, perhaps, the chief stepping-stones to his subsequent eminence. He fixed his residence in London; and in 1724 published, in No. 36 of the *Plain Dealer*, his ballad of *William and Margaret*, the work by which he is now best remembered. The spirit of this piece seems to have been caught from the two old ballads, *William's Ghaist* and *Fair Margaret*, yet there is sufficient originality in its simple feeling and graceful diction to entitle Mallet to be called its author. It was about this time, when he was moving in the society of the chief wits of the day, and was desirous of expunging every trace of his humble origin, and even of his native country, that Mallet assumed the name by which he is now known. In 1728 appeared his *Excursion*, a servile imitation of the style of Thomson, who was then becoming known to the world. His poem on *Verbal Criticism*, published in 1773, was a satire on Bentley, written to please Pope. About this period Frederick Prince of Wales, who was at variance with his father, and was courting popularity by patronizing literary men, appointed Mallet his under-secretary, with a salary of L.200; and in 1740 employed him, conjointly with Thomson, to write *The Masque of Alfred*, in honour of the birthday of the Princess Augusta. This piece Mallet afterwards entirely altered, and produced, without any great success, on the stage of Drury Lane. In 1742 he married his second wife, the daughter of Lord Carlisle's steward, and received L.10,000 as her dowry. Not content with the liberal fortune which he now possessed, Mallet was yet mercenary enough to become the hired tool of any one. He was employed by Lord Bolingbroke, in 1749 to traduce his deceased patron Pope, in a preface to that nobleman's *Patriot King*, and received as his paltry payment the bequest of his lordship's works. With equal servility did he lend himself to government for the purpose of directing the public vengeance against the ill-fated Admiral Byng. The admiral was shot in 1757, and Mallet received a pension. Towards the close of his life Mallet repaired to France for the benefit of his health, but on feeling that his constitution was rapidly giving way, he returned to England, and died soon afterwards, in April 1765. The base character of the man was now revealed in glaring distinctness. It was discovered that a Life of the great Duke of Marlborough, which he had been hired to write by a legacy of L.1000 from the old duchess, and by a pension from the second duke, and which he had professed during his latter years to be composing, was not even begun.

Mallet was an avowed infidel. "As a writer," says Dr Johnson, "he cannot be placed in any high class. There is no species of composition in which he was eminent. His dramas had their day—a short day—and are forgotten; his blank verse seems to my ear the echo of Thomson." Besides the works already mentioned, Mallet wrote *Eurydice*, *Mustapha*, and *Elvira*, tragedies; *Britannia*, a masque; *Amyntor* and *Theodora*, a poem; and a *Life of Bacon*. His *Ballads and Songs, with Notes and Illustrations*, accompanied by a Memoir by Frederick Dinsdale, were published in London, 1857.

Mallet, *Paul-Henri*, an eminent historian, was born at Geneva in 1730, of a family distinguished for the great number of notable men whom it has produced. After completing his education with marked success, he became tutor to the Count of Calenberg, and in 1752 was appointed regius professor of belles-lettres in the university of Copenhagen. The duties devolving on Mallet in this position were discharged with signal ability; but as the French language was not much cultivated in Denmark at that time, the number of his auditors was for the most part very limited. He employed his leisure time in the study of the old Norse language, and brought to light many important historical facts respecting the ancient inhabitants of the north, almost entirely unknown to their descendants of Denmark or the Scandinavian peninsula. The reception which his work met among the learned drew upon the professor the attention of the king, who appointed him instructor in the French language and literature to the young prince, afterwards Christian VII. In 1760 Mallet returned to his native city; and after having filled the chair of history in the college of Geneva for four years with distinguished success, he was chosen a member of the Council of the Two Hundred. Unmistakeable marks of admiration flowed in upon Mallet from persons of rank and distinction; from the landgrave of Hesse-Cassel, from the Czarina of Russia, and from the Earl of Bute, whose son, Lord Mountstewart, Mallet accompanied to Italy, and afterwards to England, where he was presented to the royal family, and was asked by the queen to write a history of the House of Brunswick. On returning to his native country, Mallet resolved to spend the evening of his days in studious retirement and tranquillity, when, in 1792, the revolution of Geneva, in which he warmly espoused the cause of the aristocratic party, deprived him of what moderate fortune his talents had purchased. Owing to the events of the war, the pensions which he had received from the English queen and from the landgrave of Hesse ceased to be forthcoming; but the government of France, on being made aware of the circumstance, granted Mallet an allowance, which he did not live long to enjoy. He died at Geneva, of an attack of paralysis, on the 8th of February 1807.

Mallet was an associate of the Academy of Inscriptions of France, a member of the academies of Upsal, Lyons, and Cassel, and of the Celtic Society. His principal works are,—*Introduction à l'Histoire de Danemark, ou l'on Traité de la Religion, des Mœurs, des Lois, et des Usages des Anciens Danois*, Copenhagen, 1755-56. This work, the most popular of Mallet's in this country, was translated into English and extended by Bishop Percy in 1770, and has recently been republished, with further additions by Blackwell, in Bohn's Antiquarian Library, under the title of *Mallet's Northern Antiquities*. The *Histoire de Danemark*, from A.D. 714 to 1699, Copenhagen, 1758-65-77, 3 vols. 4to; *De la Forme du Gouvernement de Suéde, avec quelques Pièces Originales, contenant les Lois Fondamentales et le Droit Public de ce Royaume*, Copenhagen, 1756, 8vo; *Histoire de la Maison de Hesse*, 1766-85, 4 vols. 8vo; *Histoire de la Maison de Brunswick*, 1767-85, 4 vols. 8vo; *Des Intérêts et des Devoirs d'un Republicain, par un Citoyen de Raguse*, Inverdun, 1770, 8vo; *Histoire de la Maison et des Etats de Mecklenbourg*, Schwerin, 1796, 1 vol. 4to: it only came down to 1503, and was never finished. *Histoire des Suisses ou Helvétiens*, Geneva, 1803, 4 vols. 8vo; *Histoire de la Ligue Hanseatique*, Geneva, 1805, 8vo; *Mémoirs sur la Literature du Nord*, Copenhagen, 1759-60, 6 vols. 8vo. Also a *Traduction du Voyage de* Will. Coxe *en Pologne, Russie, Suède, et Danemark*, Geneva, 1786, 4 vols. 8vo, with the *Voyage en Norvége*. He also published a new and enlarged edition of the *Dictionnaire de la Suisse*, by Tscharner, Geneva, 1788, 3 vols. 8vo. (See *De la Vie et des Ecrits de P. H. Mallet*, by I. C. L. S. Sismondi, Geneva, 1807, 8vo.)

Mallet-Prevost, *Henri*, the eldest brother of the preceding, was a geographer of some note, born at Geneva in 1727, and died at the same place in 1811.

Mallet-Dupan, *Jacques*, kinsman of the former, and a royalist writer of great power and originality during the French revolution, was born at Geneva in 1749. He was one of the conductors of the *Mercure de France*, and edited the *Mercure Britannique*, published in London during his residence in that city in 1798-99. He died at Richmond in 1800. (See *Memoirs and Correspondence of Mallet-Dupan*, by Sayous, 2 vols. 8vo, London, 1852.)

MALLICOLLO, or Manicola, one of the largest of the New Hebrides group of islands in the South Pacific, in S. Lat. 16. 30., and E. Long. 167. 57. It is about 54 miles in length, and from 15 to 21 in breadth, while it rises to a considerable height. A great part of the surface is covered with forests. Mallicollo was discovered by Quiros in 1606, and visited by Cook in 1774. The inhabitants are diminutive, ugly, and in the lowest state of barbarism.

MALLOW, a parliamentary borough and market-town, county of Cork, Ireland, situate on the N. bank of the Blackwater, 19 miles N.N.W. of Cork, and 145 miles S.W. of Dublin. The high road between Cork and Limerick crosses the river here by a bridge of three arches, at the other end of which stands the suburb of Ballydaheen, included in the parliamentary borough. The town consists of one main street nearly parallel with the river, and is well paved, and lighted with gas. The principal buildings are,—a parish church, a Roman Catholic chapel, two Methodist chapels, an Independent meeting-house, an infirmary, court-house, bridewell, workhouse, spa-house, and barrack. To the W. of the town are to be seen the ruins of an old castle; the whole of the surrounding country is rich and fertile, and contains a number of gentlemen's houses. The town has no manufactures of importance, nor is the river navigable; but a considerable retail trade is carried on here, and a great number of visitors are attracted by the mineral spring which formerly enjoyed the reputation of a holy well, and is still highly prized in cases of dyspepsia, &c. (See Cork County.) In the neighbourhood of the city there are several large flour-mills, and in the town itself tanneries and salt-works. The borough sends one member to Parliament; and the population in 1851 was 5436. Registered electors (1853) 243.

MALMEDY, a town of Prussia, province of Lower Rhine, and government of Aix-la-Chapelle, stands 21 miles S.S.W. of the town of that name, on the S. bank of the Warge. It has three churches, one of them very handsome, a school, and a justice-of-peace court. The manufactures consist chiefly of cotton and woollen stuffs, leather, lace, paper, soap, and glue. There are here also mineral springs, little inferior in quality to those of Spa, but not much frequented. Pop. (1849) 4259.

MALMESBURY, William of, an old English historian, descended by his father's side from the Normans, and by his mother's from the Saxons, was born in Somersetshire about 1095 or 1096. At an early age he entered the monastery of Malmesbury, where he subsequently became librarian and precentor. He is also said to have declined the abbotship. From his youth Malmesbury was an enthusiastic devotee of literature. He explored the chief monastic libraries in the kingdom, and with equal ardour perused books of poetry, divinity, biography, and history. His care in correcting his style is seen by the changes in the four several editions of his *De Gestis Regum* that appeared during his lifetime; and no less evident in his writings is his scrupulous regard for historic truth. His numerous and apposite quotations from Latin authors show that he possessed an acquaintance with their works alike wide and intimate. Malmesbury was in high repute in his own day, and was patronized and befriended by Robert Earl of Gloucester, natural son of Henry I. The date of his death is generally fixed at 1143; but the fact that his *Historiæ Novellæ*, published in 1142, was afterwards subjected to a thorough revisal and emendation, evidently from his own hand, seems to indicate that he must have lived considerably longer.

The following is a list of his works;—*De Gestis Regum*; *Historiæ Novellæ*; *De Gestis Pontificum*; *De Vita Aldhelmi*; *De Vita S. Dunstani*; *Vita S. Patricii*; *Miracula S. Benigni*; *Passio S. Indracti*; *De Antiquitate Glastoniensis Ecclesiæ*; *Vita S. Wulstani Episcopi Wigorniensis*; *Chronica*; *Miracula S. Elfgifæ*; *Itinerarium Joannis Abbatis Meldunensis versus Romam*; *Expositio Threnorum Hieremiæ*; *De Miraculis Divæ Mariæ*; *De Serie Evangelistarum*, in verse; *De Miraculis B. Andreæ*; *Abbrevatio Amalarii de Ecclesiasticis Officiis*, and *Epitome Historiæ Aimonis Floriacensis*. Malmesbury's *De Gestis Regum*, *Historiæ Novellæ*, and *De Gestis Pontificum*, were published by Savile in his *Scriptores post Bedam*, 1596 and 1601. The *De Vita Aldhelmi* and the *De Antiquitate Ecclesiæ Glastoniensis* appeared in Gale's *Scriptores XV.*, Oxford, 1691. The former of these works and the *Vita S. Wulstani* are printed in the second volume of Wharton's *Anglia Sacra*. In 1815 was published *The History of the Kings of England, and the Modern History of William Malmesbury*, translated by the Rev. John Sharpe, 4to, London. This translation has been reprinted in Bohn's Antiquarian Library, 1847.

MALMESBURY, a parliamentary borough and market-town of England, county of Wiltshire, situate on a hill near the Avon, which winds almost round it, and is spanned by several bridges, 17½ miles N.N.W. of Bath, and 86 miles W. of London. The town consists of three main streets not very regularly laid out. The houses are for the most part built of stone; and in the market-place stands an ancient octagonal cross, richly ornamented with carved work, supposed to be as early as the reign of Henry VIII. The town was formerly defended by walls and a castle of some strength, and it possessed a very large abbey, covering 45 acres of ground, of which little now remains except the church, an excellent specimen of early English architecture. Besides this, there is the church of St Mary's; and of a third, St Paul's, little more than the tower now remains. There are also places of worship belonging to the Independents, Baptists, and Moravians, two schools, a savings-bank, and a market-house recently erected. A considerable amount of wool manufacture was formerly carried on here, but now the manufactures are unimportant. There is a silk mill; and tanning, brewing, and lace-making are carried on to a small extent. The place, however, is on the decline, and the inhabitants are mainly engaged in agricultural pursuits. Cattle markets are held here monthly, and three great horse and cattle fairs in the year. The market-day is Saturday. The chief importance of Malmesbury is derived from its antiquity and historical interest. According to the ancient chronicles, a monastery was founded here in the seventh century, which, after being twice burnt by the Danes in the ninth and tenth centuries, finally rose to be one of the principal establishments of the kind in the W. of England, and in the reign of Edward III. was raised to the dignity of a mitred abbey. In the time of Stephen the town, which had then been newly fortified, was an object of some contention, and in the civil war of Charles I. it was taken from the royalists by Sir William Waller in 1643, but it was soon recovered, and again taken a short time after. At this time, too, the church received great injury, and was reduced to its present ruined state. This borough has returned members to Parliament since the time of Edward I. Previous to the Reform Act it had two representatives, but the number has now been reduced to one. The town is famous for its connection with several writers of eminence. St Aldhelm, a Saxon writer of the seventh century, and Thomas Hobbes, sometimes called the "Philosopher of Malmesbury," were born here; and William of Malmesbury, one of the best of mediæval historians, was, during the greater part of his life, a monk of the abbey. Pop. (1851) 6998.

MALMÖ, a seaport-town of Sweden, capital of the laen or province of the same name, stands on the E. shore of the Sound, nearly opposite Copenhagen, from which it is 16 miles distant; N. Lat. 55. 40., E. Long. 13. The town, which stands on a level plain, is well laid out with regular and well built streets, and has a fine square in the centre. Malmö was formerly very strongly fortified, being surrounded by walls and ditches, and protected by a castle; but the walls have been demolished, and only the castle now remains, which is used as a prison and barracks. The square is adorned by a handsome avenue of limes and other trees; and the principal buildings in the town are two churches, one of which has a fine interior and a large organ. The harbour, which consists of a roadstead and an artificial inner basin, is only accessible to small vessels. Being, however, the principal commercial town in the fertile province to which it belongs, it carries on an extensive trade, particularly in grain and brandy. The manufactures are considerable, consisting of woollen cloth, starch, gloves, stockings, hats, carpets, tobacco, soap, &c. Steamers ply regularly between this and Copenhagen, accomplishing the distance in two hours. Pop. 10,203. The laen or province of the same name, of which Malmö is the capital, is one of the richest in Sweden, and comprises an area of 1774 square miles. It is bounded by Christianstad on the N. and E., by the Baltic on the S., and by the Sound on the W. The surface is for the most part level, though occasionally diversified with hills. It includes several lakes. The produce of this district consists of corn, potatoes, hemp, hops, tobacco, and fruits; and the horses and cattle reared here are said to be the finest in Sweden. Corn and cattle are the chief articles of export. Pop. of laen (1850) 253,084.

MALO, St, a seaport of France, capital of an arrondissement of the same name in the department of Ille-et-Vilaine, is situated on the island of Aron, which is joined to the land by a narrow causeway called the Sillon, about three-quarters of a mile in length, 45 miles N. by W. of Rennes; Lat. 48. 39. N., Long. 2. 1. W. The harbour is secure, being sheltered from the sea by the island and the Sillon; but the great number of rocks render the approach both difficult and dangerous. To the W. of the town there is a roadstead, which is separated from the harbour by a chain of rocks, and defended by seven forts. The harbour is dry at low water, but has recently been improved by the formation of a large wet dock. The harbour is much frequented: vessels are fitted out here for India and for the whale fisheries, and a good deal of ship-building is carried on. The chief articles of export are the products of the surrounding country, together with straw hats, woollen and linen fabrics; and it imports sugar, indigo, spices, and other Indian and Chinese wares. The town is strongly fortified, the defences being constructed by Vauban. At the entrance of the town from the Sillon there is an ancient castle of an imposing appearance, built of granite, and having a strong tower at each corner. The fortifications rise abruptly from the water's edge, and the whole surface of the island is covered by the town. The houses are lofty and built of stone; and there is a square in the centre, in which stands the cathedral, the Hotel de Ville, and the episcopal palace. Not far from the town is St Servan, which is sometimes considered as a suburb of St Malo. The manufactures of St Malo consist mainly of sail-cloth, cordage, fish-hooks, hosiery, and soap. This town seems to have been founded in the tenth century; but the island on which it stands was the seat of a monastery as early as the sixth century. Before the rise of Brest, this town was the first seaport in France on the ocean; and Cartier, one of its seamen, was the discoverer of Canada. During the wars with Great Britain the privateers of St Malo did so much injury to their enemies, that the town was three times bombarded by the British, in 1693, 1695, and 1758, but always without success. Pop. (1851) 9383.

MALONE, Edmund, the well-known editor of Shakespere, was the son of an Irish judge, and was born at Dublin in 1741. After graduating at Trinity College in his native city, he studied at the Inner Temple, London, and was called to the bar in 1767. Inheriting, however, a competent fortune, he soon exchanged his professional labours for the more congenial pursuits of literature. In 1780 Malone published two supplementary volumes to Stevens' edition of Shakespere; and his own edition of the great dramatist, in 11 volumes 8vo, appeared in 1790. He also, in 1796, defended the fame of Shakespere by exposing the spuriousness of the MSS. attributed to the poet by the Irelands. Malone was one of the executors of Sir Joshua Reynolds, and in 1797 published the works and a memoir of that great painter. He died in 1812. An edition of his Shakespere, which he had greatly improved during the latter part of his life, was published in 21 volumes, in 1821, by his friend Mr James Boswell. His other works are,—*Cursory Observations on the Poems attributed to Thomas Rowley*, 8vo, London, 1782; *The Prose Works of John Dryden, accompanied with a Memoir*, 1800; and *The Works of William Gerald Hamilton, with a Sketch of his Life*.

MALPAS, a market-town of England, Cheshire, situate on an eminence overlooking the Dee, 13 miles S.S.E. from Chester. It has a fine old parish church, a grammar-school, and several charitable institutions. The Marquis of Cholmondeley, whose castle is in the vicinity, takes the title of viscount from this place. Pop. of parish (1851) 5710.

MALPIGHI, Marcello, an eminent physician and anatomist, was born near Bologna in 1628. He studied medicine in that city, and graduated as doctor in 1653. In 1656 he became professor of medicine in the university of Bologna, but was promoted during the same year by Frederick II. of Tuscany to the medical chair at Pisa. There his intercourse with Borelli, the mathematician, tended greatly to convince Malpighi of the propriety of applying experimental researches to the study of medicine. He was soon forced, however, by declining health, to return to his former situation at Bologna; but in 1666 was called to the office of principal professor at Messina. The opposition, however, with which he was assailed by the advocates of the old school of medicine in that city, induced Malpighi to resign his chair after an incumbency of four years. From Bologna he was summoned in 1691 to Rome, to occupy the position of principal physician to Pope Innocent XII. The discharge of his new duties was rendered burdensome by attacks of gout, palpitation, and other diseases, and he died of apoplexy in 1694. Malpighi's discoveries relate chiefly to the structure of the skin and of the secreting glands. He also devoted much attention to the organization of plants and the lower animals. His chief works are,—*Observationes Anatomicæ de Pulmonibus*, Bologna, 1661; *Epistolæ Anatomicæ de Lingua, de Cerebro, de Externo Tactûs Organo, de Omento, de Pinguedine et adiposis Ductibus*, 12mo, Bologna, 1661–65; *De Viscerum Structurâ*, 4to, Bologna, 1666; *Dissertatio Epistolica de Formatione Pulli in Ovo*, 4to, London, 1666–73; *Dissertatio Epistolica de Bombyce*, 4to, London, 1669; and *Epistola de Glandulis Conglobatis*, 4to, London, 1689. His grand work *De Anatome Plantarum* appeared in 1669. A selection of his works, under the title of *Opera Omnia*, was published in 2 vols., London, 1686. His *Opera Posthuma*, edited by P. Regis, professor at Montpellier, was published at London in 1697.

MALT. See BREWING, and DISTILLATION.

MALTA (anciently *Melita*), an island in the Mediterranean, between Sicily and Africa, 52 miles S.S.W. of Cape Passaro in Sicily. Length 17 miles, breadth 9 miles, area 98 square miles; N. Lat. (of Valetta) 35. 53., E. Long. 14. 31. It has been supposed by some that this island corresponds to one or other of those mentioned by Homer in the *Odyssey*, but this is exceedingly doubtful. The earliest historical information we have respecting Malta is, that it was colonized by the Phœnicians, and used by them as a station in their long trading voyages to the pillars of Hercules and the Atlantic. At a later period we find the island mentioned as a Carthaginian colony; and although there are some traces of a connection between Malta and the Sicilian Greeks, the particulars of this are not known, nor is there any reason to believe that it was ever in other hands than those of the Phœnicians and Carthaginians. In the first Punic war, Malta was laid waste by the Romans in the year 257 B.C.; but it does not seem to have surrendered finally to that power till the beginning of the second Punic war, when it was taken by Tiberius Sempronius. It then became a part of the province of Sicily, and was raised to the dignity of a municipium. Under the Roman commonwealth it seems to have been in a flourishing condition. It is now established beyond all reasonable doubt, that this island was the scene of the shipwreck of the Apostle Paul. During the period of the Roman empire little is heard of Malta, but on the partition of the empire it formed part of the eastern portion, until it was conquered by the Vandals in the fifth century. The Romans, however, regained it under Belisarius in 533 A.D., and kept possession of it till it was conquered by the Arabs in 870. The Arabs engaged to a considerable extent in piratical expeditions, by which means they acquired great wealth, and they retained possession of the island till they were dispossessed by Count Roger the Norman in 1090. The government was then put into the hands of the nobles, clergy, and representatives of the people, popularly elected. The fortunes of Malta were now united to those of Sicily, which belonged to the Normans from 1090 to 1189, to the German emperors from 1189 to 1258, to France from 1258 to 1282, and to the House of Aragon from 1282 till the time of Charles V., who inherited it as King of Aragon. That monarch, in order to secure the island, which was now chiefly important as a military station, without the expense of maintaining a garrison, made a grant of Malta and Gozo, along with Tripoli, to the Knights of St John, who had shortly before been expelled by the Saracens from their former station at Rhodes. When once firmly established here, it was not long before the knights were able to render good service by frequent expeditions against the pirates from Africa which then infested the Mediterranean. This, however, did not fail to draw upon them the vengeance of the Turks, who made an unsuccessful attempt on Malta. This taught the knights the necessity of securing their position, and they accordingly constructed the extensive and strong defences which still remain. The prizes taken by the cruisers in the expeditions against pirates supplied in a great measure the funds required, and the fortifications were constructed by the joint labour of knights, citizens, and peasants. In the year 1565, while La Valette was grand master, Solyman sent against Malta a fleet of 159 vessels. with 30,000 troops, besides a great number of other ships with provisions, ammunition, &c. The whole number that could be opposed to these was 700 knights and 8500 Maltese soldiers. The attack on the castle of St Elmo, which was defended by 300 knights and 1300 Maltese, commenced on the 24th of May. The besieged defended themselves with great courage and vigour, their most formidable weapons being large hoops covered with inflammable materials, which were set on fire, and then hurled blazing from the walls among the assailants. In the first attack the Turks lost 3000 men, and the Christians only 20 knights and 100 Maltese; but the losses of the besieged were supplied by La Valette with others from the burgh and St Angelo, as long as the communication was left open. At length the furious and incessant cannonade of the Turks had levelled the walls of the castle to the rock on which they stood. On this a general assault was again made with the utmost fury; but it was withstood by the knights with equal courage and determination, and although the loss of the knights was great, they were again strengthened by reinforcements the next day. The Turks now completely isolated the castle by drawing an intrenchment between it and the other forts, and soon afterwards renewed the attack. The defence was now desperate, and a fearful contest ensued, which was only terminated by the approach of night; and after La Valette had in vain attempted to send assistance, the knights determined to die at their posts, and during the night they received the sacrament. The next day saw the end of this heroic defence: no quarter was asked or given; the knights all perished at their posts, and the Turks entered the desolated fortress over the dead bodies of its defenders. Notwithstanding the urgent necessity and the repeated request of the grand master, no assistance was sent from Sicily; yet no thought of surrender was for a moment entertained. The siege of the remaining forts was still carried on, and in order to prevent the approach of the Turkish vessels, the Maltese erected stockades, and where the water was too deep, placed booms across the harbour. The Turks sent swimmers with hatchets to cut away these obstructions; but they were met and discomfited by Maltese sailors, who swam from the forts, until, perceiving that no advantage was gained by such contests, the assailants at length desisted from this mode of warfare. The besiegers being now reinforced by a body of Algerians, under the command of the son of Barbarossa, made an attack on the forts with 4000 men, who, though they succeeded in planting their standards for a moment on the battlements, were hurled back by the knights, and all their entreaties for mercy being answered by shouts of "St Elmo," they were massacred till only 500 remained, most of whom were desperately wounded. The assaults, however, still continued, and although always unsuccessful, the numbers of the brave defenders were gradually but surely diminishing. On one occasion, when the Turks deceived their adversaries by a false attack, even the women and children shared in the defence, bringing food to the knights, and stones to repair the walls. But in spite of all, the Turks were on the very point of victory when a sally from a different part of the defences caused a panic among the assailants by the apprehension that the Sicilians had come to the rescue. Till the end of August the attacks were carried on with the utmost fury, and repulsed with incredible courage; but when preparations were being made for the final attempt, the long-expected aid at last arrived, and the Turks not daring to abide more than one encounter with the Sicilians, raised the siege, and took refuge in their ships. During the siege the Christians lost 260 knights and more than 7000 soldiers, and the Turks 25,000. After the departure of the enemy, the handful of knights who remained commenced to rebuild their city, in which they were aided by pecuniary contributions from most of the sovereigns of Europe, and from the distant knights of the Order. The new city was begun in 1566 and finished in 1571, and was called La Valetta, after the brave defender of the island—a name which it still bears. After this time the knights distinguished themselves greatly in the battle of Lepanto in 1571. They also employed themselves in defending the coasts of the Mediterranean; and although the Turks once again (in 1601) threatened Malta, they were immediately repulsed. The knights still preserved in their original strictness the rules of the Order, and strengthened the island by new fortifications, besides building an aqueduct for supplying Valetta with water, and a lazaretto for the sufferers from the plague, which visited Malta in 1669. Great assistance was rendered by the knights of Malta to the European states against the Turks and Africans, in protecting and securing the commerce of the Mediterranean. The earthquake in Calabria and Sicily, in 1783, gave them one of the last opportunities for displaying that chivalrous humanity and beneficence which were the ancient characteristics of their Order. They set out in their ships by night, and did great service to the wretched sufferers at Messina and Reggio. But the French revolution came on, and proclaimed in word and deed that the age of chivalry was gone. The property of the Order in France, Spain, and Italy was confiscated; and finally, in 1798, the island surrendered to the fleet of Bonaparte on its way to Egypt. A garrison of 4000 men was left by the French to defend Malta; but after the battle of the Nile the inhabitants rose against the French, who were besieged in the city of Valetta. A small body of British troops subsequently arrived to the aid of the Maltese, and the French surrendered after a blockade of two years. Provision was made in the treaty of Amiens that Malta should be restored to the knights, on condition that the Maltese should be admitted to the Order; but this was strongly opposed by the Maltese themselves, and the island remained in the possession of Britain till it was finally secured to her at the general peace. Since then, Malta, with the adjoining island of Gozo, has been a part of the British empire.

The coast of Malta is steep and rocky, especially on the S.W., where there is no harbour between Marsa Scirocco on the S.E, and Antifaga on the W. On the W. coast there is the harbour of Magiarro; but on the N.E. coast are the harbours of St Paul, St George, St Julian, and the two harbours of Valetta, which are the largest in the island, and are separated from each other by a projecting tongue of land, on which the city is built; that to the N.W. is called Marsa Musceit, in which there is a small island, used as a quarantine station; while the other, lying to the S.E., is called the Great Harbour. The surface of the island for the most part slopes from the S.W. to the N.E.; and there is a ridge of hills running across the island to the N.W. of Valetta, known by the name of Bengemma, from which numerous smaller ridges run off in various directions. Mount Bengemma, which is the highest point in Malta, reaches the height of 590 feet above the sea. On the western side the cliffs rise perpendicularly from the sea to a height of 300 or 400 feet, while on the E. the coast gradually slopes down to the water's edge. The central ridge divides the island into two parts, in the more easterly of which all the towns are situate; and besides being strong by nature, this barrier has been additionally secured by an intrenchment, known by the name of the Nasciaro Lines. There are neither rivers nor lakes in Malta, and the only places where any swamps occur are St Paul's Bay and the Great Harbour at Valetta, where the sea has retired and left a marshy tract of ground, from which unhealthy vapours are believed to arise. The geological character of the island is chiefly calcareous: there are strata of limestone of various kinds lying on calcareous freestone, and beneath the latter is found a layer of marl. Many petrified animal remains and an abundance of sharks' teeth are to be found here. The rocks of Malta belong to the tertiary formation, and to the older or newer pliocene. The rock is covered in most parts by sand and a rich red clay; but here and there the bare rock projects through the soil; and the country has in general a very dry and barren appearance, except after it has been refreshed by a fall of rain. The vegetation is scanty, and very few trees are to be seen. There are two kinds of stone found here, which are much used for building purposes,—the one is hard and the other soft, though there are many intermediate kinds. The hardest is a coarse sort of marble, remarkable for strength. The other is a soft kind of calcareous sandstone, which is found in much greater quantities, and is used for the ordinary purposes of building. It is very light, absorbent, and easily cut, but when exposed to the air it is apt to crumble away. Alabaster is found in considerable abundance in Malta, but especially in Gozo. In the steep cliffs on the sea-coast there are a great number of remarkable caves and grottos, some of them very large. Many of them are situate at the level of the sea, so that the waves dash in with great noise, while others are higher up the rocks. One of the largest of these is near the promontory called Benghisa, to the W. of the Marsa Scirocco Bay, and extends more than 200 paces into the rock. The soil of Malta is, like its rocks, calcareous, and owes much of its fertility to the porous character of the soft sandstone, which is broken up by the natives, and mixed with soil. Where the rock is too hard for this, they bring soil from other lands, and form it into terraces, using the large stones to form walls, in order to prevent the soil from being washed away. The soil, however, is very fertile, frequently yielding two crops a-year, and never requiring to lie fallow. Cotton is the principal produce of the Maltese islands. Corn is grown in sufficient quantities to supply the inhabitants. Vines are cultivated, but the wine is of inferior quality; figs and oranges are very abundant, the latter especially being of excellent quality. Of animals found in the island, the Maltese dog and hawk were formerly much sought after, but the former of these species is now believed to be extinct. Many of the domestic animals in this island are remarkable for their breed, especially mules and asses. Snakes are found in Malta, but they are harmless,—a fact which the inhabitants ascribe to the miraculous influence of the apostle Paul. The bees are famous for the excellence of their honey, and some have supposed that the island was on this account called *Melite* by the Greeks. Fish is got here in great abundance, and many of the kinds are excellent, especially the dory, rock cod, and a species of whiting called *lupo*. A remarkable shell-fish, called the *Pholas dactylus*, is found at Malta, which bores for itself a hole in the soft rock, so as to give to many parts of the shore a very remarkable appearance.

The climate of Malta is very warm, and in summer the heat becomes oppressive. The greatest heat is between 80° and 90°, while the thermometer never falls below 46°. The radiation of the sun's rays from the rocks tends to increase the heat, and the stones and walls get sometimes so heated during the long days as to retain a high temperature during the night, and render the nights in summer excessively hot and oppressive. The winter at Malta, which extends from October to May, is very pleasant and salubrious. There are no regular land and sea breezes, owing probably to the fact that the temperature of the land remains so high during the night. The most frequent winds are those which flow from the S.E. and N.W.; but the former, the siroccos, are very hot and unhealthy, and generally prevail between August and October. Sudden gusts of heated air occasionally blow across from the coast of Africa, which would be exceedingly dangerous and destructive were they not very limited in duration, in most cases not exceeding half a minute. Snow is unknown in Malta, but hail frequently falls during the winter months. Between the months of December and February rain falls frequently, and often in violent storms; in March the weather is more dry and settled. In April and May the island is refreshed by occasional showers; while during the summer there is not a cloud to darken the clear sky, or mitigate the fierceness of the sun's rays. September and October are the most agreeable months; the temperature is then cool, and the air calm and bracing. This period is called by the Maltese the little summer, or St Martin's summer. Thunder-storms are not frequent, and occur chiefly in spring. The sky is generally clear, sometimes so much so that the summit of Etna, at a distance of 128 miles, is distinctly seen.

The capital of the island is Valetta, situate between the two harbours of Marsa Musceit and the Great Port, on the E. coast of the island. The promontory on which it stands, which was anciently called Mount Sceberras, is nearly 2 miles long, and about three-quarters of a mile broad, and forms a sort of ridge, like the back of an animal, sloping down to the sea on either side, and at the further extremity. At its point stands the fort of St Elmo, with one of the best lighthouses in the Mediterranean. The principal streets run along the ridge, and others, shorter, branch off at right angles; while a carriage drive runs round the whole city between the houses and the fortifications. The ground on which the city is built is so steep that the principal streets in Valetta consist of flights of stairs; but this contributes greatly to facilitate the cleaning of the thoroughfares. The houses are built of stone, with flat roofs, after the eastern fashion. Wood is little used in the houses of Valetta. The streets are well lighted, and paved with the hard stones of the island and lava from Mount Etna. Water is supplied by the aqueduct built by the knights; but every house has a tank for collecting the rain water, and there are numerous wells. The fortifications are exceedingly strong, and almost impregnable; so that at the last siege it could only be reduced by famine. The land side of the town is defended by five lines of fortifications, mounted with 1000 pieces of ordnance; and it is calculated that it would require 25,000 soldiers to man the entire defences in their whole extent. Of the public buildings of Valetta, one of the most remarkable is the cathedral or collegiate church of St John, which contains the tombs of some of the grand masters, as well as the chapels of the knights of the different nations. The pavement of this church is inlaid in marble with the arms of the grand masters; and there is a remarkable silver railing, which owes its preservation, during the French possession of Malta, to its having been disguised by paint. The church is also remarkable for a series of paintings representing the chief events in the life of St John the Baptist, one of which is by Caravaggio, but is not in good preservation. Another remarkable building is the church of San Pubblio, which contains under it a large catacomb, in which are to be seen many skeletons and bones of the ancient friars. Besides these, the other public buildings are,—the palace, which contains several fine pictures and an armoury; the lodges or *auberges* of the knights; the government library; the university, treasury, palace of justice, &c.; all of which, and especially the library and the lodges of Castile and Provence, are well built, and distinguished by great taste and simplicity in architecture. The library consists of about 100,000 volumes; and adjoining it there is a museum, which contains many remains of antiquity. The harbours of Valetta are very good. That called Marsa Musceit is now used as a quarantine harbour. The Great Harbour is very much frequented, and is so strongly fortified that no ship could force a passage in past the batteries which stand on each side of the entrance. A large dry dock has recently been added at an expense of L.100,000, which is capable of receiving the largest ships and steamers.

The only other town of importance in the island is Città Vecchia, or Città Notabile, anciently called *Medina*, which was formerly the capital, and stands near the centre of the island about 6 miles W. of Valetta, on a high ground overlooking nearly the whole of the island. It is the seat of a bishop, and contains a handsome modern cathedral; but the chief interest of the place is derived from the catacombs, which are of considerable extent, about 15 feet below the surface. There are some remarkable ancient remains at a place called Casal Crendi, near the S. coast, but little or nothing is known of their origin. The island of Gozo is situate about 4 miles to the N.W. of Malta. Its form is oval, its greatest length is 10 miles, greatest breadth 5 miles; area 16 square miles. It was originally called *Gaulos* by the Greeks, and *Gaulum* by the Romans; but the Arabs corrupted this name to *Gaudese*, from which has come its modern appellation. The coasts, especially to the S., are steep and rugged. The geological structure of the island is the same as that of Malta, but the soil is better and it is more highly cultivated. The surface is undulating, with several conical hills, apparently of a volcanic nature. In the N.W. some of the hills attain a considerable elevation. Gozo contains no town, but the inhabitants dwell in six small villages. There are two principal forts,—Rabato in the centre, and Chambray in the S., near to the latter of which is the best landing-place and anchorage. Sailing and rowing boats ply daily between Valetta and Gozo, the passage being only 8 miles in length. Between the two larger islands lies Comino, abounding in rabbits, and several other islets and rocks, all of which belong to Malta and Gozo.

The Maltese are of middle stature, strong, and dark in complexion, and the women are remarkable for their oriental style of beauty. The character of the country people resembles that of the Spanish; but in the towns a union of the qualities of the French and Greek nations may be observed. The men are active and industrious, being chiefly employed in agriculture and stone-cutting. They also make the best sailors of any in the Mediterranean. The dress of the lower orders consists of a loose shirt, above which they wear a jacket adorned with silver or gold buttons, and a long scarf wound round their waist. They have also short drawers reaching to the knee, and shoes somewhat resembling the sandals of the ancients. In winter they wear woollen caps, with hoods falling down behind, and in summer large straw hats. The dress of the women is extremely picturesque, consisting of a cotton under-garment, a blue petticoat, a corset with sleeves, and an upper garment which opens at the side. Their usual head-dress consists of a black silk veil, called *faldetta;* but many of the higher classes, both of men and women, have adopted the English and French fashions of dress. The manners of the Maltese are not refined, but they are in many respects superior in their moral character to the other inhabitants of southern Europe. Drunkenness is almost unknown; and the favourite beverages of all classes are coffee and iced water. Tobacco is smoked to a considerable extent. Music and dancing, along with horse and boat races, are the principal amusements in the island.

The government of Malta is exercised by a governor appointed by the crown, with a salary of L.4800 per annum, along with a council of eighteen members, eight of which are elected by the Maltese. The governor presides in the council, in which he has two votes, and a veto on all its proceedings. This constitution was first established in 1849. The total number of acres under cultivation in the three islands in 1854 was, 45,182, of which 7545 were wheat, 6753 meschiato, and 7873 cotton. The quantity of uncultivated ground was 14,274 acres. In the same year there were in the islands 3748 horses, 4396 head of cattle, 9489 sheep, and 3323 goats. The number of ships that entered the port in 1854 was 4783, with a tonnage of 886,790; and of those that cleared in the same year, 4551, with a tonnage of 844,242. There are no returns of the value of the imports and exports of Malta.

The amount of public revenue and expenditure since the year 1850 is as follows:—

Years.	Revenue.	Expenditure.
1850	L.129,293	L.125,362
1851	133,080	119,307
1852	127,729	123,068
1853	123,305	138,034
1854	123,772	141,304

Of the total revenue for 1854, L.76,493 was derived from customs, and L.17,311 from rents, exclusive of land. Of the expenditure in the same year, L.47,927 was employed on the fixed establishment; L.13,744 on pensions, retiring allowances, &c.; L.16,297 on hospitals and charitable allowances; L.694 on education; L.28,429 on public works, buildings, roads, &c.; and L.6200 on military expenses. The number of schools in the islands in 1854 was 32, containing a total of 4969 scholars. The number of births in the year 1854 was 4698; of deaths, 3981; of marriages, 711. Pop. (1854) 131,401.

MALTE-BRUN. See Brun.

MALTHUS, Thomas Robert, was born in 1766, at the Rookery, in the county of Surrey. His father, Daniel Malthus, a gentleman of good family and independent fortune, much occupied in classical and philosophical pursuits, was the friend and correspondent of Rousseau, and ultimately one of his executors. From the age of nine or ten, until the time of his admission at Cambridge, young Malthus remained under private tuition, and was sometimes a solitary pupil in the house of his tutor. He had for his instructors Richard Graves, author of the *Spiritual Quixote*, and Gilbert Wakefield, the editor of Lucretius and other classics, and the correspondent of Mr Fox.

In 1784 young Malthus was removed from Mr Wakefield's house to Jesus College, Cambridge, where he obtained prizes for declamations both in Latin and in English, and on taking his degree in 1788, his name appeared in the *Tripos* as the ninth wrangler. He also found time for the cultivation of history, literature, and poetry; and in 1797 he was made fellow of his college. Having about the same time entered into holy orders, he undertook the cure of a small parish in Surrey, but he occasionally resided in Cambridge on his fellowship, for the purpose of pursuing with more advantage the course of study to which he was attached. In 1798 appeared the first edition of his great work, an *Essay on the Principle of Population as it affects the Future Improvement of Society, with Remarks on the Speculations of Mr Godwin, M. Condorcet, and other writers*, in 1 volume octavo. In this production the general principle of population which Wallace, Hume, and others, had very distinctly enunciated before him, though without foreseeing the consequences which might be deduced from it, was clearly expounded, and some of the important conclusions to which it leads, in regard to the probable improvement of society, were likewise stated and explained; but his proofs and illustrations were still imperfect, and he himself was yet scarcely aware of the whole extent and bearings of the subject. The book, however, was received with some surprise, and excited considerable attention, as an attempt to overturn the theory of political optimism, and to refute, upon philosophical principles, the speculations, then so much in vogue, of Godwin and others, as to the indefinite perfectibility of human institutions. (With respect to Malthus's views, see the articles Colony and Population.) In 1799 Malthus sailed for Hamburg in search of materials for the exposition of his grand principle, along with Dr Ed. Daniel Clarke and others. He visited Sweden, Norway, Finland, and part of Russia, the only countries at that time open to English travellers. Of this tour he has left other memorials besides those embodied in his own work, and amongst these may be mentioned the valuable notes which have since served to enrich the last volume of Dr Clarke's Travels. During the short peace of Amiens, he visited France and Switzerland; exploring all that was most interesting in these countries, and continuing, wherever he went, to collect facts and documents for the illustration of the principle he had announced, and the completion of his work. In 1805 he was appointed professor of modern history and political economy at Haileybury, a situation in which he remained until his death. It has sometimes been insinuated that Malthus was indebted to his father for those new views of population which first appeared in the essay already noticed, and which subsequently attracted so much attention. For this surmise, however, there appears to have been no foundation whatever. That the mind of Mr Malthus was set to work upon the subject of population in consequence of frequent discussions between his father and himself, he has fully admitted; but no two individuals ever entertained opinions more opposite, or differed more completely respecting the very principle which the one is alleged to have suggested to the other.

Exclusive of the *Essay on Population*, the principal productions of Mr Malthus were,—*An Inquiry into the Nature and Progress of Rent*, 1815; *The Principles of Political Economy*, 1820; and *Definitions in Political Economy*, 1827. But none of these made any permanent addition to his fame. The Inquiry in regard to Rent is an ingenious, and probably also an original speculation; but it has since been ascertained that the theory explained by Malthus in his tract, had been discovered and set in a very clear light by Dr Anderson in an Essay on the Corn Laws, published in 1776. The treatise on Political Economy is very ill arranged, and is in no respect either a practical or a scientific exposition of the subject. It is in great part occupied with an examination of parts of Mr Ricardo's peculiar doctrines, and with an inquiry into the nature and causes of value. Nothing, however, can be more unsatisfactory than these discussions. In truth, Mr Malthus never had any clear or accurate perception of Mr Ricardo's theories, or of the principles which determine the value in exchange of different articles. His *Definitions* have all the faults of his *Political Economy*, and never exercised any influence.

The latter years of Mr Malthus's life were passed in the society of his family, in the exercise of his ministerial and official duties at the college, and in the cultivation of the studies more immediately connected with them. Most of the statesmen of his time, and all the eminent political economists, embraced his opinions in regard to population, and, in their several departments, paved the way for that practical application of his principles, in regard to the poor laws, which has since taken place. He was honoured with distinctions from several sovereigns of Europe, and elected a member of the most eminent literary and scientific societies, particularly the National Institute of France and the Royal Academy of Sciences at Berlin. He was one of the founders of the Political Economy Club, and of the Statistical Society. He died at Bath of an affection of the heart, on the 29th of December 1834.

MALTON, NEW, a municipal and parliamentary borough and market-town of England, in the North Riding of Yorkshire, is situate on a hill on the right bank of the River Derwent, which forms the boundary between the North and East Ridings, 18 miles N.E. by N. of York, and 217 N. by W. of London. The town is clean and well built, and the principal streets meet in a central market-place, in which the town-hall stands. There are two ancient churches, one of which exhibits a fine specimen of Norman architecture; and places of worship for Baptists, Methodists, Independents, Wesleyans, and Unitarians. Malton possesses national, British, and infant schools; and there is also a public grammar-school in the suburb of Norton, which stands on the other side of the Derwent, and is joined to Malton by a handsome stone bridge. There are also in the town a theatre, public rooms, a literary institute, a dispensary, and a savings-bank.

The town has several breweries and tanneries, but its prosperity is principally derived from its trade, which is considerable, the river being navigable to a short distance above the town. Agricultural produce, such as flour, corn, bacon, butter, &c., are sent to Hull, Leeds, &c. The market-day is Saturday, and fairs take place three times a-year. The quarter sessions for the North Riding, together with a county court, are also held here. Malton stands on the York and Scarborough Railway, and it returns two members to Parliamant. Pop. (1851) 7661.

Old Malton, which is included in the parliamentary borough, is situate about a mile N.E. of the new town, on the same side of the river. Some Roman remains have been found here, and it is by some believed to occupy the site of the ancient *Camulodunum*. In the year 1150 a priory was founded here, the remains of which, as well as an ancient church, are still to be seen. Shortly afterwards the Norman family of De Vesci, or Vesey, built a castle here, which was demolished by Henry II. The town was afterwards rebuilt in the reign of Stephen. Old Malton contains a Wesleyan chapel and several schools, and is remarkable for its lime quarries, and also for the ancient Roman remains that have been found in the neighbourhood.

MALUS, ETIENNE LOUIS, the discoverer of the laws of the polarization of light by reflection, born at Paris on the 23d of June 1775, was the son of Anne Louis Malus du Mitry, and of Louisa Charlotte Desboves, his wife.

His father had a place in the Treasury of France, and gave him at home an excellent education in mathematics and in the fine arts, as well as in classical literature, with which he rendered himself so familiar as to retain many passages of the *Iliad* in his memory throughout life. At seventeen he was admitted, after a severe examination, as a pupil of the School of Military Engineers; and about the same time he amused himself with writing a regular tragedy in verse on the death of Cato. He soon distinguished himself in his military studies, and he was about to obtain a commission as an officer, when an order of the minister Bouchotte imputed to him the offence of being a suspected person, probably on account of the situation held by his father, and he was dismissed from the school. He was then obliged to enter the army as a private soldier in the fifth battalion of Paris, and he was employed in this capacity upon the fortifications of Dunkirk. Here he was soon distinguished by M. Lepère, the director of the works, as superior to his accidental situation; and he was selected as one of the young men who were to constitute the members of the *Ecole Polytechnique*, then to be established upon the recommendation and under the direction of Monge, who immediately chose him, from a previous knowledge of his merit, as one of the twenty who were to be made instructors of the rest. This body constituted at that moment the only refuge of the sciences in France, and the enthusiasm of its members was proportionate to the advantages which they enjoyed, and to the importance of the trust committed to them. In the three years which he passed in this institution he was much employed, amongst other applications of the higher geometry, in pursuing the mathematical theory of optics, a department of science in which he was afterwards so eminently to distinguish himself by experimental discoveries. He was then, however, obliged to abandon for a time the pursuit of scientific investigations, and he was admitted into the corps of engineers; with the seniority of his former rank in the school. He served in the army of the Sambre and Meuse; he was present at the passage of the Rhine in 1797, and at the affairs of Ukratz and Altenkirch. Whilst he was in Germany, he formed an attachment with Miss Koch, the daughter of the chancellor of the university of Giessen; and he was on the point of marrying her, when he was obliged to join the Egyptian expedition. He was present in that campaign at the battles of Chebreïs and of the Pyramids; he was also present at the affair of Sabish, at the siege of El Arish, and at that of Jaffa. After the surrender of that place, he was employed in the repairs of the fortifications, and in the establishment of military hospitals. Here he was attacked by the plague, and fortunately recovered from it without any medical assistance. He was then sent to fortify Damietta; he was afterwards at the battle of Heliopolis, at the affair of Ceraim, and at the siege of Cairo. After the capitulation with the English, he embarked on board the transport "Castor," and arrived in France on the 26th of October 1801. His health was exhausted, and his spirits were broken by fatigue and anxiety; but his attachment to his betrothed bride was undiminished, and he hastened to Germany to fulfil his engagement. His fidelity was rewarded, during the eleven years that he survived, by the most constant and affectionate attention on the part of his wife; and she died a year or two after him, a victim to the same disease which had been fatal to her husband.

He had, however, enough of strength and vigour of constitution remaining to enable him, besides the official superintendence of the works carrying on at Antwerp and at Strasbourg, to pursue the study of his favourite sciences; and upon occasion of a prize question proposed by the Institute, he undertook the investigation of the extraordinary refraction of Iceland crystal, which the experiments of Dr Wollaston had previously shown to agree very accurately with the laws laid down by Huygens; and besides completely confirming all Dr Wollaston's results, he had the good fortune greatly to extend the Huygenian discovery of the peculiar modification of light produced by the action of such crystals, which Newton had distinguished by the name "Polarity," and which Malus now found to be produced in a variety of circumstances, independently of the action of crystallized bodies. It seems natural to suppose that the investigation of the laws of the internal reflection of light at the second surface of the crystals, must have led him to the discovery of the effects of oblique reflection in other circumstances; but according to Biot, there was more of accident in his actual progress; for he informs us that Malus had been looking through a piece of crystal at the image of the sun, reflected from the windows of the Luxembourg, to the house in the Rue d'Infer, where he lived, and that he was much surprised to find one of the double images disappear in a certain position of the crystal, although the next day, at a different hour, he could no longer observe the phenomenon, from the alteration of the angle of incidence.

The merit of his discovery was soon acknowledged by his election as a member of the Institute, as well as by the adjudication of a biennial medal from the Royal Society of London, on the foundation of Count Rumford. It has been thought creditable to the Royal Society to have conferred this distinction in the time of a war between the two countries; but if any credit were due for only doing justice conscientiously, it would attach, on this occasion, to those members of the council who saw their own optical speculations in great danger from the new mass of evidence which appeared likely to overthrow them, at least in the public opinion, and who were still the most active in offering this tribute of applause to the more fortunate labours of a rival.

Nor was the remuneration of Malus confined to empty honours only; from the liberality of the French government, he obtained promotion in his own profession *as a military man;* and this not for services performed in the field, nor even in a difficult and dangerous expedition to unknown regions, but for experiments made with safety and tranquillity in his own closet. That government had not carried the refined principle of the division of labour so far as to resolve that all public encouragement should be limited to the precise department in which a public service had been performed; and hence a mark of distinction, which a gentleman could accept without degradation, was not deemed an incommensurate remuneration for a discovery in abstract science. Such a refinement, which has been practically introduced into our own country, might appear, to a man who had a heart, something worse than sordid; he might fancy that a great nation, as well as a great individual, should treat its dependents, "not according to their deserts, but after its own honour and dignity." If, however, a person in office happened to have anything like a heart about him, the outcry of an indiscriminating opposition would soon teach him to silence its dictates.

1. M. Malus's first publication appears to have been a paper "On an Unknown Branch of the Nile," in the first volume of the *Décade Egyptienne.* 2. He presented to the Institute a mathematical "Traité d'Optique," before the completion of his experiments on double refraction; it was published in the *Mémoires présentés à l'Institut,* vol. ii., Paris, 1810. 3. His more important discoveries were first made known in the second volume of the *Mémoires d'Arcueil,* Paris, 1809, 8vo; and again, 4, in the "Theory of Double Refraction," *Mém. Près. à l'Inst.,* vol. ii., a paper which obtained a prize on the 2d of January 1810. 5. In a short "Essay on the Measurement of the Refractive Force of Opaque Bodies," contained in the same volume, he employs the method, before made known by Dr Wollaston, for conducting the experiment, and computes the forces concerned upon the Newtonian hypothesis, applied, however, in a manner somewhat arbitrary to the circumstances of the problem. 6. Remarks on some "New Optical Phenomena," *Mèm. Inst. Sc.,* 1810, p. 105, Paris, 1814, read 11th March 1811. This paper is principally intended to prove that two portions of light are always polarized together in opposite directions, and that no part of the light concerned is destroyed, "as Dr Young had been inclined to suspect." The author found that light transmitted obliquely through a number of parallel glasses at a proper angle, becomes at last completely polarized. M. Arago had discovered a case which appeared to be an exception to the general law of the polarization of transmitted light; but it was afterwards readily explained from the theory of the production of colours by interference, as applied to transmitted light. A letter containing the substance of this paper was published in Thomson's *Annals,* iii. 257, April 1814, on occasion of some discoveries of Sir David Brewster, which had been supposed to be wholly new. 7. "On Phenomena accompanying Refraction and Reflection," p. 112, read 27th May, showing the universality of polarization at a proper angle, and examining the effect of a metallic surface. 8. "On the Axis of Refraction of Crystals," p. 142; describing an apparatus for finding the properties of bodies with respect to polarized light, applied to the determination of the axis of crystals, and to the examination of the structure of organized bodies, which appear in general to have certain axes of polarization, as well as those which are manifestly crystallized.

The zeal and energy of Malus supported him to the last, not only in the continuance of these interesting investigations, but also in his duties as an examiner at the *Ecole Polytechnique.* He died on the 24th of February 1812, universally regretted by the lovers of science in all countries, and deeply lamented by his colleagues, who said of him, as Newton did of Cotes, that if his life had been prolonged, we should at last "have known something" of the laws of nature. (For a full account of Malus's discoveries see the Sixth *Preliminary Dissertation,* chap. v., § 2. See also Delambre, *M. Inst.* 1816, p. xxvii.; Biot, in *Biographie Universelle,* xxvi., Paris, 1820.)

MALVERN, GREAT, a watering-place of England, county of Worcestershire, 8 miles S.W. by S. of Worcester, and 119 N.W. by W. of London, occupies a beautiful site on the eastern side of the Malvern Hills. There is an ancient church at Malvern, which formerly belonged to a monastery founded by Edward the Confessor, and was purchased by the inhabitants on the dissolution of the monastery. This church is one of the finest specimens of Gothic architecture in the kingdom. The town is irregularly built, but there are many fine villas and houses in the neighbourhood. It has a chapel of the Countess of Huntingdon's Connection, a handsome library, national and endowed schools, a dispensary, &c. Malvern is chiefly noted as a fashionable watering-place, and it is much frequented on account of its medicinal waters and its general salubrity. Baths and hotels have been built, and gardens and walks laid out, for the accommodation of the visitors. Pop. of parish (1851) 3763.

MALVERN, *Little,* is a village about 3 miles to the S. of the former. The Malvern Hills extend N. and S. for nearly 9 miles, with a breadth of 1 or 2 miles, and separate Worcestershire from Hereford and Monmouth. They rise with a gentle slope, and the three greatest elevations are the North Hill, Worcestershire Beacon, and Herefordshire Beacon, the last of which is 1444 feet above the level of the sea.

MALVOISIN, or MAWMOISINE, WILLIAM DE, some time chancellor of Scotland, was bred in France, and has been thought by some to have been a native of France. Soon after his coming to this country, he was made one of the *clerici regis,* and archdeacon of St Andrews, in which latter capacity we find him present at the christening of the young prince, afterwards King Alexander II. He was constituted chancellor of Scotland on the death of Hugh, Bishop of Glasgow, 6th September 1199, about which time also he was elected into the see of Glasgow, and was consecrated the following year by a special precept from Pope Innocent III. In 1202 he was translated to St Andrews, when he seems to have resigned the chancellorship. In September 1208 he dedicated the new cemetery at the monastery of Dryburgh. (Chalmer's *Caledonia,* ii. 339.) In 1211 we find him, and Walter, Bishop of Glasgow, possessed of legatine powers from Rome, and assembling at Perth a great council of the clergy and people, to press upon them the pope's will and command that an expedition be undertaken to the Holy Land. In 1214 he attended the coronation of King Alexander II., and is said to have set the crown on the head of that monarch. The following year he went with the Bishops of Glasgow and Moray, and Henry, Abbot of Kelso, to the fourth Lateran council, where he remained till 1218; and in the ninth year of King Alexander II. he made a mortification for the soul of King William. He brought into this country from the Continent some Orders of monks and mendicants, till then unknown here, and had convents of Dominican friars erected at Aberdeen, Ayr, Berwick, Edinburgh, Elgin, Inverness, Montrose, Perth, and Stirling, and monasteries for the monks of Valliscaulium at Pluscardine in Moray, Beaulieu in Ross, and Ardchattan in Argyll. He wrote lives of the popish saints Ninian and Kentigern; and it was to him and in his time that Pope Innocent III. sent the decretal letters which appear in the *Corpus Juris Canonici* (*Decret. Greg.*, b. iii., tit. 49, c. 6) to the King of Scots; and (b. iii., tit. 24, c. 9; b. iv., tit. 20, c. 6; and b. v., tit. 39, c. 28) to the Bishop, Archdeacon, and Abbot of St Andrews respectively. The zeal of this bishop for holy church is evident; but it was not his only passion, for on one occasion we find that he deprived the abbey of Dunfermline of the presentation to two churches, because the monks had failed to provide him wine for supper. Fordun says the monks had indeed supplied wine, but the bishop's attendants had drunk it all up. In a composition regarding tithes, anno 1277 (Connel, *Tith.* ii. 413), there is reference to an ordinance, "Willielmi dicti Mawvoisin, Episcopi Sancti Andreæ." Malvoisin continued Bishop of St Andrews till his death, which happened on the 9th of July 1238. (Fordun; Keith's *Bishops;* Chalmers's *Caledonia,* vol. iii., p. 616.)

MALWAH, an extensive province of Hindustan, situate principally between the 22d and 23d degrees of N. Lat. On the N. it is bounded by the provinces of Ajmeer and Agra, on the E. by Allahabad and Gundwaneh, on the S. by Khandesh and Berar, and on the W. by Ajmeer and Gujerat, being in length about 220 miles, and in average breadth 150. Malwah is a central and mountainous region, but with a regular descent from the Vindhya Mountains, which extend along the north side of the Nerbuddah. From these mountains numerous streams descend in every direction, whence they flow N. and S., joining in the former case the Chumbul, and in the latter the Nerbudda. The principal of these are,—the Parbutty, the Chumbul, Betwa, Sinde, Sopra, and Cane; the Mahy, which has its source in the Vindhyan Hills, and also the Nerbuddah, flow in the opposite direction from the abovementioned rivers, and lose themselves in the Gulf of Cambay. The land, notwithstanding its elevation, is extremely fertile, the soil being in general a fine black mould, which produces cotton, opium, sugar, indigo, tobacco, and grain, in large quantities, beside furnishing pasture for numerous herds of cattle. The tobacco, particularly that of the district of Bilsah, is highly esteemed, and carried to all parts of the country. The opium is also much esteemed, and is cultivated to a great extent. Barley is not cultivated, owing to the unfavourable soil; and rice only in a few detached spots, which lie convenient for water. The chief towns are,—Oojain, Indore, Bopal, Bilsah, Seronge, Mundessor, Burseah, and Mundoo. The rivers are not navigable; and being an inland province, the commerce is carried on by means of land carriage. The chief articles of export are cottons, coarse-stained and printed cloths, which are sent in large quantities to Gujerat and to Mirzapoor, on the Ganges, and thence forwarded to Calcutta; the root of the *Morinda citrifolia,* and opium, which last drug is exported to the adjacent provinces, especially to Gujerat and Cattywar, whence it is smuggled eastward. The province of Malwah was rendered tributary to the Patan sovereigns of Delhi in the thirteenth century. During the fourteenth and fifteenth centuries it was governed by independent sovereigns of the Patan or Afghan race. Malwah was subdued, and continued to form a province of the Mogul empire until the death of Aurungzebe in 1707, when it was invaded and overrun by the Mahrattas, and separated from the Mogul dominions, about the year 1732. The ancient land-holders, however, still retained some forts, which they resolutely defended, until their invaders conceded to them a portion of the rents of the neighbouring villages. These people are called Grassias; and one of them retained a mud fort within 10 miles of Oojain in 1790. There were other petty chiefs who held hereditary possession of certain parts of the country, and who possessed each one or more strongholds, which were frequently defended with obstinacy against the rulers of the province. In the southern division of Malwah the Bheels or savage tribe are found in considerable numbers, especially among the mountains contiguous to the Nerbuddah and Taptee rivers. Malwah was the seat of the Pindarrie power, whence they issued in predatory bands to pillage and destroy the country. In 1818, after the war against them had been brought to a successful conclusion, they took refuge in Malwah, their ancient haunt, and still meditated new insurrections. But they were pursued with such activity by the British troops under the orders of Sir John Malcolm, that they were driven to the hills; and being pursued to their fortresses, they were in the end entirely routed and dispersed. The great object of the British in penetrating into these remote parts was to put down entirely the spirit of disorder and rapine by which all ranks appeared to be animated, having been long inured to the most unbounded license, and to restore peace in those regions of Central India which had long been the scene of anarchy. For this purpose, having subdued the leaders of the Patan mercenaries and the Pindarries, Sir John Malcolm distributed his troops in such convenient positions as to awe the disturbers of the public peace into submission, and to preclude all attempts at violence by the disorderly bands who were still lingering in the country, and ready for any violence. By a judicious combination of conciliation with firmness, Sir John Malcolm succeeded in restoring order in the distracted country. The result of his arrangements was the expulsion of the disorderly bands by which the public peace was disturbed, the restoration to power and security of the rulers of the different petty states, and the return to their homes of peaceable and industrious classes, who, during the reign of terror and anarchy, were forced to hide their heads in obscurity. The same talents and statesman-like policy were displayed by Sir John Malcolm in his transactions with the Grassia, Rajpoot, and Bheel freebooters, who were reclaimed from their wild habits, and converted into trustworthy soldiers and industrious cultivators. (E. T.)

MAMERS, a town in the department of Sarthe, in France, capital of an arrondissement of the same name, is situate near the source of the Orne, in a hilly and barren country, 27 miles N.N.E. of Le Mans. The town contains two squares, but the streets are few and unpaved. The principal buildings are,—the government offices, a college, a theatre, and a prison; and there are manufactories of linen, calicoes, hosiery, &c., besides tanneries and breweries. There is also a considerable trade in grain, wine, brandy, wax, cattle, and sheep. The town is supposed to have derived its name from a temple of Mars erected in this district by the Romans; and was anciently a place of considerable strength. After being for some time in the possession of the English, the fortifications were destroyed by them in 1428. Pop. (1851) 5960.

MAMMALIA.

History.

Mammalia (from *Mamma*, breast) is a term in natural history applied to those animals which give suck to their young; and it consequently includes not only all quadrupeds, commonly so called, but also the cetaceous tribes, or whales. The Mammalia form the first class of the Animal Kingdom, and may be defined as follows: They produce their young alive, and nourish them by means of milk; they possess a heart with two ventricles,—lungs,—warm blood,—a voluminous brain, with a corpus callosum,—complete senses,—a muscular diaphragm between the chest and abdomen, and seven cervical vertebræ.[1]

The natural history of quadrupeds certainly forms one of the most interesting and important departments of zoology. The class itself exhibiting a vast range in size and structure, from the delicate harvest mouse to the enormous whale, presents us with so many species of the highest economical value to the human race, that selfishness alone, or at least the desire of immediate personal advantage, would suffice to induce their attentive study, independent of any more philosophical consideration. The study of the organization of quadrupeds has also been of great advantage in throwing a clear and steady light on several points which would otherwise have long continued extremely obscure in the physiology of man. We need scarcely say to any one who has witnessed even their external aspect, that the quadrumanous tribes, or monkeys, are nearly allied in conformation to the human race; and that the lord of the creation, in spite of his spiritual attributes, his intellectual nature, and immortal destiny, holds many things in common with the brutes that perish. He is himself a mammiferous animal, and closely allied, in organization and many physical qualities, to the other orders of his class; nor can it be expected that experience, derived from the practical observation of the other three great classes of the vertebrated animals, to wit, birds, reptiles, and fishes, will ever avail to the physiologist in a way so full and satisfactory as that deduced from the careful study and observance of the mammiferous tribes. At least the latter furnish by far the most immediate and logical affinities to the human race. In regard to the economical uses of quadrupeds, it is scarcely necessary to say, that they supply us with the most truly precious of our earthly gifts. What in themselves are the ingots of pure gold, or the most dazzling lustre of barbaric gems, compared in value with the ample covering of our fleecy flocks? Without the horse, the ox, the sheep, and the dog, how different would be the social, commercial, and political conditions of the most civilized tribes of the human race! Without his rein-deer how would the forlorn Laplander support either his "sleepless summer of long light," or the desolate gloom of a snow-enshrouded winter? Without the enduring camel the desert sands of Africa, if not lifeless solitudes, would at least be nearly impassable to the human race, and as useless for all commercial purposes as an ocean without ships.

History.

It is true, indeed, that every being in nature, the most apparently insignificant production of a Divine Creator, is necessarily deserving of the most studious attention, on the part not only of the philosophical naturalist, but of every intelligent and instructed mind; yet it must be readily admitted, that the creatures with which the great mass of mankind have the most immediate connection, and in the history of which we are most interested, either from the advantages they yield, or the injuries they inflict, are those which may naturally claim our chief attention. Indeed all branches of natural history are in themselves so interesting, independent of any economical result, that each in its turn, when steadily regarded, seems to claim the precedence; and we fear that certain of the treatises on the subject which have already appeared in this work, may have been deemed as somewhat too extended by those who had not previously considered the beauty and excellence of such topics. Indeed we doubt not that many may still regard an insect chiefly as a thing to be trampled on, and a reptile as one to be more carefully avoided; and it probably results from this wide spread persuasion, that even modern authors not seldom commence their entomological or other expositions of the so-called inferior tribes, with something like an *apology* for discussing the attributes of such lowly creatures. To us it seems to be enough to know that they have been created—that they consequently form parts of that magnificent circle of organic life—of those wonders "manifold" which we are desired to magnify, and the least obtrusive of which are well worthy of the most deliberate study by the deepest mind. We scarcely think, then, that an "apology" is necessary between man and man for any degree of devotion to the works of God; and this, so far as concerns the mammiferous tribes with which we are now about to be engaged, will probably, from the undeniable importance of the subject, be at once admitted. Few are so sceptical as to doubt the merits of beef and mutton, and every one may feel kindly disposed towards a study which numbers, in its subject-matter, so many materials that feed, clothe, and enrich the human race.

We do not propose to enter into any lengthened historical exposition of this branch of science from remote periods to the present times. Such investigations may be met with in many accessible works, and would here occupy too much of that space within which we must endeavour to illustrate the more important features of the actual subject. A few brief notices, however, may not be misbestowed on the principal epochs which characterize the investigations of the human mind in this important department.

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[1] An inconvenient animal the Ai, or *Bradypus tridactylus*, Linn., is the only known quadruped hitherto supposed to present an exception to the character last above named; and it appears from recent investigations, that even this solitary exception is more apparent than real. "An isolated exception to a rule so general, and obtaining in cases of such diversified forms as those to which I have alluded, presents itself to the mind of every one accustomed to look at the general harmony of the established laws of formation, as a violation of that unity of design which constitutes one of the most interesting objects of our investigation, especially as the exception itself is abrupt and sudden, and without any of those intermediate gradations of structure by which the mind is prepared, as it were, for considerable diversities of form, and which so generally soften the transitions which the different offices of the same organ in different groups may render necessary. It was from this consideration rather than as merely correcting a generally received error, that I found, with feelings of no ordinary satisfaction, that in truth this numerical law is not departed from in the present instance, and that the animal in question forms no such exception to the general rule as had been asserted; the two vertebræ which have hitherto been considered as the eighth and ninth cervical, being in fact the first and second dorsal, each of them bearing a pair of rudimentary ribs, moveably articulated to their transverse processes by a true articular surface. This fact I have ascertained by the examination of two skeletons in my possession, one of which is an adult, and is artificially articulated, the other very young, and preserved as a natural skeleton in spirit."—See *Observations on the Neck of the Three-toed Sloth, Bradypus tridactylus*, Linn., by Thomas Bell, F.R.S., in *Transactions of the Zoological Society of London*, vol. i. p. 113.

Although among very ancient authors some valuable distinctive principles were pointed out which remained long unattended to, and have been recognised and acknowledged in their due importance only in comparatively recent times; and although the fact of our thus, with all our additional appliances and stores of knowledge, merely as it were retracing what had been ascertained and recorded by those whose mortal remains have now for so many ages mouldered in the dust, cannot but prove the value of ancient discoveries and observation; yet, upon the whole, it cannot be said that any work of a remote antiquity presents an accurate picture of the truth of nature. Fact and fable are in most instances so intermingled, and a distinct appreciation and lucid description of individual features so frequently blended with unreal or fantastic characteristics, that to derive advantage from such lucubrations, the reader would require to be as learned as his author. At least a constant watchfulness must be kept up, lest the fictions of imagination be received as the records of truth.

Although in Herodotus, the "Father of History," we find a few casual indications regarding quadrupeds, and a greater number in the later labours of Columella, Varro, Seneca, Athenæus, and Oppian, yet the ancient authors who have treated most amply of their history and attributes, are Aristotle, Pliny, and Ælian. If the ancient annalist first named deserved the title above alluded to, so with equal propriety has Aristotle been named "the Father of Natural History." His descriptions, though often incomplete, are almost always exact. The general results with which we are now familiar in the works of our great physiological naturalists must not indeed be looked for; nor can it be denied that the merest tyro in anatomy would now be astonished at his doctrines relating to the structure and functions of the brain, which he regarded as a cold spongy mass, adapted for collecting and exhaling the superfluous moisture, and intended for aiding the lungs and trachea in regulating the heat of the body. He looked upon the heart as the seat of vital fire, and not only the fountain of the blood, but the organ of motion, sensation, nutrition, the seat of the passions, and the origin of the veins and nerves. He deemed that the blood was confined to the veins, while the arteries contained an aërial spirit; and by nerves he signified not only what are now so called, but also tendons and arteries, that is, any extended *string*-like portion which the name of νευρον literally implies. The heart, he alleged, had three cavities, and that in the larger animals it either communicated with the windpipe, or the ramifications of the pulmonary artery received the breath in the lungs and carried it to the heart, while respiration was effected by the expansion of air in the lungs, by means of internal fire, and the consequent irruption of the external air to prevent a vacuum. Digestion is a species of concoction or boiling, performed in the stomach, aided by the warmth of the neighbouring viscera! "It is perhaps impossible at the present day, when the investigation of Nature is so much facilitated by the accumulated knowledge of ages in every department of physical science, by the commercial relations existing between countries in all parts of the globe, by a tried method of observation, experiment and induction, and finally, by the possession of the most ingenious instruments, to form any adequate idea of the numerous difficulties under which the ancient naturalist laboured. On the other hand, he had this great advantage, that almost every thing was new; that the most simple observations correctly recorded, the most trivial phenomenon truly interpreted, became as it were his inalienable property, and was handed down to succeeding ages as a proof of his talents, a circumstance which must have supplied a great motive to exertion. The History of Animals is undoubtedly one of the most remarkable performances of which physical science can boast. It must not, however, be imagined, that it is a work which, replete with truth, and exhibiting the well-arranged results of accurate observation and laborious investigation, is calculated to afford material aid to the modern student. To him more recent productions are the only safe guides; nor is it until he has studied them, and interrogated nature for himself, that he can derive benefit from the perusal of the treatise which we now proceed to explain."[1] We shall here avail ourselves in part of the brief abstract of the writer just quoted.

The first book of Aristotle's History of Animals contains a short description of the parts of which their bodies are composed, and of the differences in the mode of life of living creatures. He asserts that man alone is capable of design, for although many other animals are endowed with memory and docility, none possesses the faculty of reflection but the human race. The sense of touch, he states, is common to all animals, and every living creature has a humour, blood, or sanies, the loss of which produces death. Every species that has wings has also two feet, and we know of no animal which flies only, as fishes swim, for such as have membranous wings likewise walk, and bats have feet, as have seals, although of an imperfect structure. In this chapter he divides animals into such as have blood, and such as have it not. Of the former (that is, the *red-blooded*), some want feet, others have two of these organs, others four. Of the latter (the *white-blooded*), many have more than four feet. Of the swimming animals, which are destitute of feet, some have fins, which are two or four, others none. Of the cartilaginous class, those which are flat have no fins, as the skate. Some of them have feet as the mollusca. Those that have a hard leathery covering swim with their tail. In regard to the mode of production, some animals are viviparous, others produce eggs, some worms. Man, the horse, the seal, and other land animals, bring forth their young entire; as do likewise cetacea and sharks. Those which have blow-holes have no gills, as the dolphin and whale. Of the flying animals, some, as the eagle and hawk, have wings; others, in place of wings, have membranes, as the bee and the beetle; while others are furnished with a leathery expansion, as the bat. Such as have feathered or leathery wings have blood (that is, red blood); but those provided with membranous wings, as insects are without blood (*i. e.* are white-blooded). Although he had previously stated that every winged species has also feet, he now propones that such as fly with wings or leathery expansions, either have two feet or none; for, says he, it is reported that there are serpents of this kind in Ethiopia. Of flying bloodless animals, some have their wings covered by a sheath, as beetles, while others have no covering, and of these some have two, others four wings. Those which are of large size, or bear a sting behind, have four, but the smaller or stingless have two wings only. Those which have sheaths to their wings, have no sting; but those which have two wings are furnished with a sting in their forepart, as the gnat. Animals are also distinguished from each other, so as to form kinds or families. These, according to Aristotle, are quadrupeds, birds, fishes, and cetacea—all of which have (red) blood. Then there is another kind, covered with a shell, such as the oyster; and another, protected by a softer shell, such as the crab. Another kind is that of the mollusca, such as the cuttle-fish; and finally, the family of insects. All these latter kinds are destitute of (red) blood. Here, then, we have a general classification of animals, which it is important should be borne in mind by whoever follows historically the stream of zoology to later times, a stream which, resembling that of certain actual waters, will be found in its downward course not only occasionally to diminish, but sometimes altogether to disappear.

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[1] Macgillivray's Lives of Zoologists, in *Edinburgh Cabinet Library*, vol. xvi. p. 57.

It has been well observed that these, and numerous other general aphorisms which we have omitted, are by no means so simple or so easily attained, as one might imagine after cursory perusal; and this will be the most readily admitted by him who possesses the most comprehensive view of the great series of animated life. This system of Aristotle, then, may be exhibited in its general features by the following form:—

Red-Blooded Animals.

QUADRUPEDS, SERPENTS, BIRDS, FISHES, CETACEA.

White-Blooded Animals.

TESTACEA, CRUSTACEA, MOLLUSCA, INSECTS.

It must not, however, be understood that Aristotle proposes any formal distribution of animals, for his ideas respecting families, groups, and genera, were extremely vague, and bear little or no relation to the views entertained in modern times. His Quadrupeds (and it is with them that we are at present mainly concerned), include both the modern Mammalia and the quadrupedal Reptiles. He divides them into those which are viviparous, and those which are oviparous; the former covered with hair, the latter with scales. Serpents are also scaly, and, excepting the viper, oviparous. Yet all viviparous animals are not hairy, for, he observes, some fishes likewise bring forth their young alive. In the great family of viviparous quadrupeds there are also many species (or genera), such as man, the lion, the stag, and the dog, and he mentions as an example of a natural genus those animals which possess a mane, as the horse, the ass, the mule, and the wild ass of Syria, which are several distinct species, but together constitute a genus or family.[1]

In his second book Aristotle enters more into minute details, many of which are curiously accurate, while others are as singularly erroneous. An instance of the latter we meet with at the commencement, when he asserts that the neck of the lion has no vertebræ, but consists of a single bone. In speaking of members, he takes occasion to describe the proboscis of the elephant, and to enter generally into the history of that gigantic quadruped. He describes the buffalo and the camel, and in regard to the latter, he mentions both the Arabian and the Bactrian kinds. He next discusses the subject of claws, hoofs, and horns, and states that some quadrupeds have many toes, as the lion, while others have the foot divided into two, as the sheep, or composed of a single toe or hoof, as the horse. His general aphorisms on the subject of horns are wonderfully accurate. He states that most (he might have said all) animals furnished with them have cloven hoofs, and that no single-hoofed animal has two horns. He might have added, "nor even one." He next treats of teeth, which, he says, are possessed by all viviparous quadrupeds. Some have them in both jaws, others not; for horned animals have teeth in the lower jaw only, the front ones being wanting in the upper. Yet all animals which have no teeth above are not horned—the camel, for example. Some have projecting teeth, as the boar; others not. In some the teeth are jagged, as in the lion, panther, dog; in others even, as in the horse and cow. No animal has horns and protruded teeth; nor is there any having jagged teeth that has either horns or projecting teeth; but the seal has them all jagged, because it partakes of the nature of fishes, which possess that peculiarity. His remarks on the shedding of teeth are, however, erroneous, and his account of the hippopotamus is inaccurate in almost every particular. But in treating of monkeys he notices their great resemblance to the human race, the peculiar formation of their hind feet, and their perfect fitness to be used as hands. He then gives a general account of oviparous quadrupeds, and next proceeds to that of birds and fishes; but with none of these departments are we at present concerned.

Aristotle's third book is chiefly what may be called physiological. His fourth treats of those animals which he regards as destitute of blood; but even here we find interspersed various interesting and accurate observations on the higher classes. Thus he enumerates the organs of sensation, stating that man, and all the red-blooded and viviparous animals, possess five senses, although in the mole vision is defective. Yet he pretty correctly describes the eye of that subterranean dweller, shewing that although it is covered by a thickish skin (it is not of course so covered, though the aperture is small), it presents a conformation similar to that of other animals, and is furnished with a nerve from the brain. He says that all viviparous quadrupeds not only sleep but dream; but that it is uncertain whether the oviparous ones indulge in dreams, although they sleep. The fifth, sixth, and seventh books are occupied by the subjects of generation and parturition, and the eighth relates to the food, actions, migrations, and other circumstances in the history of animals. The ninth contains a multitude of topics not apparently at all related to each other, but which have in some way successively suggested themselves to the mind of the author. It is indeed believed that whatever remains to us of Aristotle's History or Animals may be looked upon as fragmentary; but in whatever light it may be viewed, it cannot be otherwise regarded than as entirely deficient in method. We continually meet with the most abrupt transitions, the subject more immediately at first in view being seemingly lost sight of for the sake of indulging in digressions foreign to its nature, and we frequently find a circumstance repeated. "This work resembles the rude notes which an author makes previous to the final arrangement of his book; and such it may possibly have been. Of descriptions properly so called there are few, those of the elephant, camel, bonasus, crocodile, chameleon, cuckoo, cuttle-fish, and a few others, being all that we find."[2] It cannot, however, be denied, that notwithstanding his numerous imperfections, he did much both for anatomy and natural history, "and more, perhaps," says Dr Barclay, "than any other of the human species, excepting such as a Haller or Linnæus, could have accomplished in similar circumstances."[3] The great importance justly attached to his writings as the founder of natural history, has induced us to present a more extended sketch of his views and doctrines than we can afford to other ancients. In our remaining notices we shall therefore be extremely brief.

Nearly three centuries and a half elapsed between the death of Aristotle and the birth of Pliny, who came into the world during the reign of Tiberius, and in the twentieth year of the Christian era. He was a voluminous compiler of all that was known during his own time, and although of less accurate observation, and of more defective judgment than his great predecessor, his works are extremely curious, and of considerable value in their way. His Natural History was his latest work, and unfortunately it is the only one which has descended to the present times. It was composed, according to his own statement, of extracts from more than 2000 volumes, written by authors of all kinds, and is in truth not so much a treatise on what we now term Natural History, as a relation of all that was known (and of not a little that was imagined) concerning animals, vegetables, the mineral kingdom, the "great globe itself," agriculture, commerce, medicine, and the arts. It is divided into thirty-seven books, the eighth of which consists of notices not only regarding our mammalia proper, such as elephants, lions, tigers, panthers, camels, cameleopards, rhinoceroses, and others, but also touches on the history of dragons, serpents, and reptiles. As an exposition of natural history, strictly so called, the work is in truth of little real interest, and of no utility, and we need scarcely say that every principle of natural arrangement is utterly unknown, or disregarded.

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[1] *Ibid.* pp. 58-62.

[2] Loc. cit. p. 72.

[3] *On Life and Organization.* The best edition of the Πεϱι Ζωων ʽΙϛοϱια is that of Schneider, himself a great Grecian, and an accomplished naturalist. 4 vols. 8vo, Leipsic, 1811

The only other ancient naturalists whom we shall here name are Ælian and Oppian. The former, surnamed by reason of the sweetness of his style the Honey-tongued, flourished in the latter part of the second century, and wrote a history of animals in Greek, which abounds in foolish fables; the latter was a poet, of the early part of the third century, who is said to have received from Caracalla a golden crown for every line. Besides his works on fishing and falconry (the latter lost), he composed certain books on hunting (Cynogeticon), which, with the others, are probably still consulted by the curious, although we cannot pledge ourselves to their in any way advancing the student's knowledge of the mammiferous tribes.

When the darkest ages began to pass away, that is, when a lengthened period was concluding, during which, so far as can now be ascertained, the European mind does not seem to have been successfully exercised either in science or literature (excepting chiefly what was gained in the one from the Arabian writers, in the other from the legends of the Provençal Troubadours), we begin again to perceive the emanation of a feeble light. The expression, perhaps, should be qualified by considering the disadvantages of early writers,—their ignorance of anatomy,—and, for aught we know, the non-existence of museums. Albertus Magnus flourished during the greater period of the thirteenth century, and composed, among innumerable other works, a History of Animals. It is a remarkable production for its time. The author lived long at Cologne, where he is said to have miraculously raised flowers in winter, to please William Count of Holland. Another of his wonderful feats was the construction of a speaking automaton, which, however, was one day knocked on the head by Thomas Aquinas, the angelical doctor, who deemed it an agent of the devil. From these facts we ought probably to infer, that he possessed no mean skill in horticulture, and was an adept in mechanical philosophy. He is said, by some, to have derived his latinized name of Magnus, not so much from the greatness of his learning and celebrity, as because his family name in Dutch was *Groot.* Yet none of the Counts of Bollstadt, to whom he was akin, seem ever to have borne such name. In the greater proportion of his works, he appears either as a commentator on Aristotle (he is alleged to have been no great Grecian, and to have studied the Stagyrite chiefly through the medium of a Latin translation), or as a compiler from the Arabian writers. His History of Animals is mainly composed from Aristotle, Pliny, and Ælian. "He was a man," says Sir Thomas Browne, "who much advanced their opinions by the authoritie of his name, and delivered most conceits, with strickt enquirie into few."

Passing over about two hundred years, we have next to name some celebrated writers of the sixteenth century. Old Conrad Gesner, as we are accustomed to call him, died in the prime of life of a pestilential disease, in the year 1565. He was a native of Zurich, in Switzerland, and a very voluminous author. His only work which falls within our present cognisance is his History of Animals, which consists of five books, forming several folio volumes, the last of which was published posthumously, more than twenty years after his decease. They are adorned with numerous wooden cuts, which, as may be supposed, are more curious than accurate. This extraordinary compilation contains a critical review of whatever had been previously effected in zoology, but is itself principally composed of extracts from ancient writers. A portion of it was translated into English by Topsell, under the title of a "History of Four-footed Beasts and Serpents." Gesner's writings were long held in the highest estimation. Haller called him *Monstrum Eruditionis*, and his works on Natural History certainly contain a sufficiency of learning, and not a few monstrosities. He is said to have been the earliest individual who, being short-sighted, used the artificial advantage of concave glasses.

During the same century flourished (to use an accustomed term, although we regret to say, that, in regard to naturalists, it admits of a varied, and sometimes very doubtful interpretation) four other naturalists, all, in their way, entitled to the name of great; we allude to Pierre Belon, Hippolito Salviani, Guillaume Rondelet, and Ulysses Aldrovandi. The first three devoted themselves chiefly to fishes, and were, in fact, the founders of modern Ichthyology; the last named was more excursive and extended in his range. Bayle indeed has remarked, that antiquity does not furnish us with an instance of a design so extensive, and requiring such an amount of labour, as that of Aldrovandus. He truly far surpasses Pliny, both in length and verbosity. His works amount to thirteen volumes folio, only four of which (those on birds and insects) seem to have been published during his own life. The volume on "Quadrupeds which divide the hoof," was first digested by Cornelius Uterverius, and afterwards by Thomas Dempster, a Scotchman, professor at Bologna, and published in 1621. That on "Quadrupeds which do not divide the hoof," was likewise digested by Uterverius, and made its appearance in 1613. The volume on "Quadrupeds with toes or claws," as well as that on Monsters, was compiled from the manuscripts by Ambrosinus. The whole were afterwards reprinted at Frankfort, although it is now difficult to obtain a uniform edition. "Aldrovandus," says the Abbé Gallois, "is not the author of several books published under his name; but it has happened to the collection of natural history, of which those books are part, as it does to those great rivers which retain, during their whole course, the name they bore at their first rise, though, in the end, the greatest part of the water which they carry into the sea does not belong to them, but to other rivers which they receive; for, as the first six volumes of this great work were by Aldrovandus, although the others were composed since his death by different authors, they have still been attributed to him, either because they were a continuance of his design, or because the writers of them used his memoirs, or because his method was followed, or, perhaps, that these last volumes might be the better received under so celebrated a name." Aldrovandus is usually regarded as an enormous and insatiable compiler, without much taste or genius (the latter attribute, fortunately for encyclopædists, being not altogether essential to such an occupation), and seems to have borrowed largely, both as regards plan and materials, from his predecessor Gesner. Buffon says with great truth, that, if all that is useless or unnecessary were expunged from his works, they might be reduced to a tenth of their bulk; but we fear it may be added, with equal truth, that, if the same operation were performed on every author, not a few would be found to yield not even that priestly proportion. It is certain, however, that when

Aldrovandus treats of cocks or oxen, he does in no measure restrain himself to their natural history properly so called, but he tells us of all that the ancients have thought of them, of all that has been imagined of their virtues or their vices, their courage or character, all the miracles with which they have been connected, all the superstitions of which they have been the subject, all the comparisons which they have furnished to poets, all the attributes with which various nations have endowed them, as well as the hieroglyphics, or armorial bearings, in which they are represented; in short, of every thing that can be found or fancied in the history of cocks or oxen. It must be added, however, that, notwithstanding (possibly in consequence of) his endless redundancy, he is often extremely exact in many important particulars; and, although Baron Cuvier calls his compilation a troublesome and indigested mass, yet we know of more than one who has found it both curious and instructive. Aldrovandus, although of noble birth, and originally of prosperous fortunes, is said to have died blind in an hospital in Bologna. It was this melancholy recollection which, coming across our mind at the commencement of the present paragraph, induced us to qualify the meaning of the term *flourished*.

Notwithstanding the voluminous labours of the authors hitherto alluded to, little or no advance had been made in systematic zoology. It is indeed surprising, that, endowed with so much learning, and of course with energy and perseverance as its sources, none of these observers should have seen natural objects in the light in which they at present appear, even to the uninstructed; for the most ignorant amongst us would scarcely now arrange all mammiferous land animals and lizards in the same natural group, simply because they are characterized in common by the possession of four legs. But great advances were made in the course of the ensuing or seventeenth century. One of the earliest, and, we fear, also one of the least successful zoologists of this period, was John Johnston, descended no doubt originally from a Scottish family, but born near Lissa, a city of the district of Posen in Poland, in the year 1603. That portion of his "Historia Animalium" which treats of quadrupeds, was published at Frankfort-on-the-Maine in 1652. The plates, engraved by Matthew Merian, exhibit some improvement on those of Gesner and Aldrovandus, but the letter-press must share with theirs in the character of being in a great manner an uncritical compilation. We here pass unwillingly the great names of Redi and Swammerdam, neither of whom wrote on quadrupeds, although the physiological observations of the one, and the surprising and hitherto unrivalled researches in insect anatomy of the other, have rendered their names immortal, and, by the philosophical and inductive spirit by which they were respectively conducted, no doubt materially contributed to inspire a better and more original habit of observation than had hitherto prevailed.

The British naturalist justly regards with pride the high station occupied, towards the conclusion of the century, by the illustrious John Ray. His "Synopsis Methodica Animalium Quadrupedum, et Serpentini Generis," was published in 1693, and besides containing a systematic classification of these creatures, it describes their external forms and internal structure, and illustrates their instinctive habits by many important and interesting observations. Indeed, there are few departments of natural history which did not receive improvements from his pen. He is termed by Baron Cuvier "le premier véritable méthodiste pour le règne animal, guide principal de Linnæus dans cette partie." The great Swedish naturalist was indeed deeply indebted to Ray, and a careful and comparative perusal of the *Synopsis Quadrupedum* and of the early editions of the *Systema Naturæ*, certainly inspires a wish that the obligation had been more warmly acknowledged. The era in which Ray flourished has been justly described as the dawning of our golden age in natural history. "The peculiar character of his works," says Cuvier, "consists in clearer and stricter methods than those employed by any of his predecessors, and applied with more constancy and precision. The divisions which he has introduced into the classes of quadrupeds and birds have been followed by the English naturalists almost to our own day; and we find very evident traces of his system of birds in Linnæus, Brisson, Buffon, and in all the authors who have treated of that class of animals." We have already alluded, in our brief notice of preceding writers, to the singular absence of all effort to illustrate even the most familiar phenomena by any approach to actual observation; and this, we think, constitutes one of the great merits of Ray, that, with sufficient learning to appreciate and report the recorded studies of his predecessors, he yet looked abroad on nature with an eye of admiration and of love, from whence resulted a freshness and originality, for which we look in vain in many bulkier volumes, both of prior and of later times. "His varied and useful labours," observes the author of a recent memoir, "have justly caused him to be regarded as the father of natural history in this country; and his character is, in every respect, such as we should wish to belong to the individual enjoying that high distinction. His claims to the regard of posterity are not more founded on his intellectual capacity, than on his moral excellence. He maintained a steady and uncompromising adherence to his principles, at a time when vacillation and change were so common as almost to escape unnoticed and uncensured. From some conscientious scruples, which he shared in common with many of the wisest and most pious men of his time, he did not hesitate to sacrifice his views of preferment in the church, although his talents and learning, joined to the powerful influence of his numerous friends, might have justified him in aspiring to a considerable station. The benevolence of his disposition continually appears in the generosity of his praise, the tenderness of his censure, and solicitude to promote the welfare of others. His modesty and self-abasement were so great, that they transpire insensibly on all occasions; and his affectionate and grateful feelings led him, as has been remarked, to fulfil the sacred duties of friendship even to his own prejudice, and to adorn the bust of his friend with wreathes which he himself might have justly assumed. All these qualities were refined and exalted by the purest Christian feeling, and the union of the whole constitutes a character which procured the admiration of contemporaries, and well deserves to be recommended to the imitation of posterity."[1] Ray was born at Black Notley, in Essex, in 1628, and died at the same place in 1705.

The greatest naturalist who was, as it were, intermediate between Ray and Linnæus, or at least whose life embraced the death and old age of the one, and the birth and manhood of the other, was the celebrated French entomologist Réaumur. He was born at Rochelle in 1683, and died in 1757. His well-known *Memoires* on insects, are among the most valuable contributions which have ever been made to that department of science; but, as he did not write on mammiferous animals, we should not have introduced his name in this place, had he not been among the first in France to form an extensive museum, containing both quadrupeds and birds, and which is known to have afforded materials for the formation of M. Brisson's works.

We now arrive at the memorable epoch of Linnæus, that immortal and unrivalled naturalist, whose life and labours are now so well known, and so universally appreciated, that we deem it needless to indulge in any observations on the subject. He was born at Rashult, in the province of Smaland, in Sweden, on the 23d of May 1707, and, after reconstructing the whole arrangement of nature, inventing an unthought-of nomenclature, and bestowing upon both the organic kingdoms a lucid order which, but for him, they certainly would not have yet possessed, he died at Upsal on the 10th of January 1778. We shall merely add his curious and characteristic description of himself, substituting the pronoun "I" for the "He" of the original. "My head was prominent behind, and transversely depressed at the lambdoid suture. My hair was white in infancy, then brown, in old age somewhat grey. My eyes were of a hazel hue, vivacious and penetrating, with a remarkable power of vision. My forehead became wrinkled in after life. I had an obliterated wart on my right cheek, and another on the same side of my nose. My teeth were ineffective, having become unsound in early life from hereditary toothach. My mind was quick, easily moved to anger, joy, or sadness, quickly appeased; in youth hilarious, not torpid in age; in business extremely prompt. My gait was light and active. I committed all household cares to my wife, being myself concerned solely with the productions of nature. I brought to a conclusion whatever I commenced, and during a journey I never looked backwards." The writings of Linnæus were extremely numerous, but we have here to do only with his arrangement of the mammiferous tribes, which introduced so many clear and precise elements into what had before been little else than a chaos of darkness and uncertainty, that but few and trifling amendments have since been effected in that branch of zoology up to the present day. The first edition of his great work the "Systema Naturæ," was printed at Leyden in 1735, and consisted of only a few folio pages. Numerous editions were called for during the lifetime of the author. That usually called the twelfth (it is believed to be in reality the fifteenth) is the best, and the last which received Linnæus's own improvements. It was published at Stockholm in 1766, and from it we have made up the following abstract of his arrangement of the class Mammalia.[1]

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[1] Memoir of Ray, in *Naturalist's Library*, Entomology, vol. ii. p. 69.

Order I.—PRIMATES.

Homo, Man: two species!
Simia, Baboons and monkeys: thirty-three species.
Lemur, Macauco: five species.
Vespertilio, Bats: six species.

Order II.—BRUTA.

Elephus, Elephant: one species.
Trichechus, Walrus: two species.
Bradypus, Sloth: two species.
Myrmecophaga, Ant-eater: four species.
Manis, Manis: two species.
Dasypus, Armadillo: six species.

Order III.—FERÆ.

Phoca, Seal: three species.
Canis, Dog, wolf, fox, &c.: nine species.
Felis, Lion, tiger, cat, &c.: seven species.
Viverra, Civet: seven species.
Mustela, Marten, polecat, &c.: eleven species.
Ursus, Bear: four species.
Didelphis, Opossum: five species.
Talpa, Mole: two species.
Sorex, Shrew: five species.
Erinaceus, Hedgehog: three species.

Order IV.—GLIRES.

Hystrix, Porcupine: four species.
Lepus, Hare: four species.
Castor, Beaver: three species.
Mus, Rats and mice: twenty-one species.
Sciurus, Squirrel: eleven species.
Noctilio, A kind of bat: one species.

Order V.—PECORA.

Camelus, Camel, dromedary, &c.: four species.
Moschus, Musk deer: three species.
Cervus, Deer: seven species.
Capra, Goat: twelve species.
Ovis, Sheep: three species.
Bos, Oxen: six species.

ORDER VI.—BELLUÆ.

Equus, Horse, ass, zebra: three species.
Hippopotamus: one species.
Sus, Hog: five species.
Rhinoceros: one species.

Order VII.—CETE.

Monodon, Narwhal: one species.
Balæna, Whale: four species.
Physeter, Cachalot: four species.
Delphinus, Dolphin: three species.

The principal objection which has been found to the preceding system is derived from the alleged unnatural separation of the Orders BRUTA, PECORA, and BELLUÆ, which are chiefly detached portions of the great Order UNGULATA of Ray, and which even Aristotle had placed in juxtaposition. They have, therefore, after the ejection of certain genera into other orders, been again brought together by Baron Cuvier, in his sixth and seventh primary divisions. Yet we cannot but wonder, that with a knowledge of the nature or existence of not more than about 230 mammiferous animals (probably about a fifth part of those with which we have now some acquaintance) Linnæus should have been able to construct such a system; for it is admitted that his *genera* are for the most part natural, in as far as they contain assemblages of species which in the majority of cases have been preserved in more recent systems, although under higher denominations, and split into minor divisions. It is also admitted that, with certain exceptions (which chiefly concern the Order BRUTA), the internal contents of the orders themselves are natural groups.[2] At all events, the influence exercised by the Linnæan system was immense and immediate, and has proved continuous and abiding. Indeed, we have already had occasion elsewhere to remark,[3] that, with the exception of the purely artificial classification of Klein, and the multiplied orders of Brisson and Vicq-d'Azyr, all the systems which have appeared since the middle of the last century are indebted more or less to the labours of the immortal Swede, and may be valued almost exactly in proportion to their share in the *lucidus ordo* of the Linnæan System. Of this no one need doubt who inclines to compare with the *Systema Naturæ* of 1766, the *Systema Regni Animalis* of Erxleben (1777), the *Prodromus Methodi Animalium* of Storr (1780), or the *Elenchus Animalium* of Bodaert (1787). Nor can it have escaped the notice of the critical observer, that after thirty years of profound and philosophical research into the mysteries of the animal kingdom, the most accomplished zoologist and anatomist of the age should have finally reverted to a closer approximation to the Linnæan system, than had characterized his views at any former period of his brilliant career. When Baron Cuvier first made known, conjunctly with M. Geoffroy (in 1797), his new classification of mammiferous animals, his numerous genera were contained under no less than fourteen different orders. Just thirty years afterwards (in 1817), he published his *Règne Animal*, with many improvements in the composition and arrangement of the minor divisions, and with the addition of the Order of which he is himself so bright an ornament, but composed, so far as the Mammalia are concerned, of primary divisions exactly the same in number, and nearly the same in nature, as those divulged and established by Linnæus himself at least sixty years before. That this is the admitted opinion of many of Cuvier's own countrymen and most devoted admirers, may be inferred from the following passage, which relates to Linnæus:—"Aussi toutes ses coupes ont-elles été généralement adoptées. Tous ses ordres sont encore admis aujourd'hui par la plupart des naturalistes modernes, et particulièrement par Cuvier, qui seulement a substitué aux noms de Linné presque tous peu susceptibles d'être traduits en français, ceux de *Quadrumanes*, d'*Edentés*, de *Carnassiers*, de *Rongeurs*, de *Ruminans*, de *Pachydermes*, et de *Cétacés*. Enfin parmi ces genres (those of Linnæus) ceux meme qu'on a été obligé de subdiviser, se retrouvent encore conservés dans les classifications les plus récentes, *où elles formes des familles naturelles*. C'est ainsi, par exemple, que l'ordre des Quadrumanes comprend deux grandes familles, les Singes et les Lémuriens, qui correspond exactement au genre *Simia* et au genre *Lemur* de l'illustre legislateur de la Zoologie."[1]

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[1] A greatly enlarged but inaccurate edition, known as the thirteenth, was compiled by Gmelin, and published at Leipsic in 1788. Dr Turton's English edition, London 1806, is a translation of that of Leipsic.

[2] Swainson *On the Geography and Classification of Animals*, p. 145.

[3] See ANIMAL KINGDOM of this Work, vol. iii. p. 182.

We have entered into these details (which many may deem unnecessary), in consequence of what we sometimes perceive of a spirit adverse to the philosophical character of the great Swedish naturalist. Delighting as we do to witness whatever of talent and ingenuity is being exercised in the development of the so-called Natural System (and that every age will furnish fresh materials towards the more satisfactory solution of that great and mysterious problem we cannot doubt), we yet desire it should be borne in mind how vast are the benefits which Linnæus has conferred on natural history, and how, but for him, we should, in all likelihood, have been still straying infinitely farther from the truth,

> "And found no end, in wandering mazes lost."

All who are in any way conversant in the science, know how admirable was his tact in the discovery of the minor natural groups, though he may have frequently failed in their combination. But whatever view we may take of methods and systems, it can scarcely be doubted that no one has contributed such valuable materials for the various and not seldom discordant theorists to work upon. Let those who find these materials in any great measure intractable, bethink themselves occasionally of a homely Scotch proverb, that "a bad reaper never had a good hook."

Although Buffon cannot be regarded as a systematic author, yet his writings have exercised so strong and beneficial an influence on natural history, that we cannot pass his name unnoticed in our cursory sketch. "Il restera toujours," says Baron Cuvier, "l'auteur fondimental pour l'histoire des quadrupèdes;" and we doubt not that the splendour of his style was among the earliest and most forcible of those exciting causes which led to a general interest in this delightful study. By bringing into play a finer combination of literary and scientific attainments, a more discursive and imaginative style, and perhaps a greater power of actual intellect than had previously fallen to the lot of (at least the modern) naturalist, he relieved the science of zoology from the undeserved opprobrium of being regarded as the pursuit of inferior capacities; and by embodying his thoughts in language as attractive as had ever been employed to give expression to the workings of the human mind, even in the higher departments of literature, he gained many proselytes among those who had hitherto viewed the subject, and all its barren technicalities, with coldness if not disgust. He has no doubt exposed himself to the reproach of having utterly disregarded the necessity, in so complex and multifarious a study, of a rigorous nomenclature, and a methodised arrangement, as well as of having introduced many grave errors, not the less dangerous and deceptive that they bear the impress of genius. Many of his descriptive sketches must be regarded rather as vivid representations drawn from an exuberant and irrepressible imagination, than as accurate portraitures deduced from the observance of nature. It cannot be denied, however, that many of his general observations are extremely important, and he was among the first to call attention to the interesting subject of zoological geography, by his comparative remarks on the quadrupeds of the old world and those of America.

As it is not our intention to exhibit in detail the features of any but the more important and influential systems, we shall here briefly illustrate the progress of the science by enumerating the amount of species described by certain well-known authors, who were either contemporaneous with, or the immediate successors of Linnæus. Brisson describes 275;[2] Erxleben, 345;[3] Pennant, 412;[4] Boddaert, 344;[5] Buffon, 333 (including his supplements, and the Cetacea of La Cepede);[6] Gmelin, 440;[7] and Vicq. d'Azyr, 363.[8] Among these authors, as M. Desmarest has observed,[9] such as have indicated the highest amount of species, have been the least critical and distinctive in their enunciation of their characters. The observation applies particularly to Pennant, Gmelin, Boddaert, and Vicq. d'Azyr, who, whatever may have been their other merits (and those of our countryman were of the highest order), were in no way distinguished for a severe revisal of the facts on which they founded. It has been calculated, that, notwithstanding the additional zeal with which the natural history of quadrupeds has been of late pursued, about an eighth part of the species described by these authors remain undetermined even at the present day.

The system of Illiger departs considerably from that of Linnæus. The Berlin Professor, of whose capacity and accomplishments no one doubts, has been reproached, and not unjustly, for a needless disregard of the nomenclature of his predecessors and contemporaries, and for a love of change, which induced a French critic to accuse him,—"d'avoir inventé beaucoup plus de mots qu'il n'a fait de travaux utiles." Nevertheless, his system, which contained, at the time of its appearance (in 1811), the indication of several new and judicious genera, has been sufficiently influential to induce us to present it to our readers. He divides the entire mammiferous class into fourteen orders, containing thirty-nine families, and a hundred and twenty-five genera, as follows. We add the name of a well-known species of each genus, with a view to illustrate the nature of the group.

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[1] Isidore Geoffroy St Hilaire, in *Dictionnaire Classique d'Histoire Naturelle*, t. x. p. 66.

[2] *Règne Animal*, 1756.

[3] *Systema Mammalium*, 1777.

[4] *Synopsis of Quadrupeds*, 1771.

[5] *Elenchus Animalium*, 1785.

[6] *Histoire Generale et Particuliere des Animaux*, 1769-85; *Cétacés*, 1806.

[7] *Systema Naturæ*, 13th Ed. 1789.

[8] *Système Anatomique des Animaux*, t. ii. 1792.

[9] *Mammalogie* (Avertissement), p. 7.

Illiger defines Mammalia as vertebrated animals, breathing by means of lungs, with warm red blood, a heart with two ventricles and two auricles, a diaphragm, mammæ, a skin either hairy or bald, viviparous, giving milk.

Synopsis of ILLIGER'S *Orders, Families, and Genera.*

ORDER I. ERECTA.

Family 1. *Erecta.*

1.	Genus Homo.	H. sapiens, L.

ORDER II. POLLICATA.

Family 2. *Quadruma.*

2.	Simia, Cuv. Orang.	S. Troglodytes.
3.	Hylobates (υλοβατης, per sylvas gradiens). Gibbon.	S. Lar, L.
4.	Lasiopyga (λασιος, villosus, πυγη, anus).	S. nemea, L.
5.	Cercopithecus. Guenon or Monkey.	S. nasica.
6.	Cynocephalus. Ape, baboon.	S. silenus, L.
7.	Colobus (ϰολοβος, mutilatus).	S. ferruginea.
8.	Ateles.	S. paniscus, L.
9.	Mycetes (μυϰητης, mugiens).	S. Beelzebub, L.
10.	Pithecia.	S. pithecia, L.
11.	Aotus.	S. trivirgata.
12.	Callithrix.	S. capucina, L.
13.	Hapale (απαλος, mollis).	S. rosalia, L.

Family 3. *Prosimii.*

14.	Lichanotus (λιχανος, digitus, index). Indri.	Lemur indri, L.
15.	Lemur . Maki.	L. mongoz, L.
16.	Stenops (στενος, angustus, ωψ, oculus). Lori.	L. tardigradus, L.

Family 4. *Macrotarsi.*

17.	Tarsius. Tarsier.	Didelphis macrotarsius, L.
18.	Otolicnus (ωτολιϰνος, auriculis magnis). Galago.	Lemur Galago.

Family 5. *Leptodactyla.*

19.	Chiromys. Aye aye.	Sciurus madagascariensis, L.

Family 6. *Marsupialia.*

20.	Didelphis. Opossum.	Didelphis marsupialis, L.
21.	Chironectes (χειϱ, manus, νηϰτης, natator).	Lutra minima.
22.	Thylacis (ϑυλαξ, saccus, marsupium). Perameles.	Didelphis obesula.
23.	Dasyurus.	D. viverrina.
24.	Amblotis (αμβλωσις, abortus). Wombat.	Wombatus fossor.
25.	Balantia (βαλαντιον, marsupium). Phalangista. C.	Didelphis orientalis, L.
26.	Genus Phalangista.	Didelphis petaurus.
27.	Phascolomys.	Phasc. fusca.

ORDER III. SALIENTIA.

Family 7. *Salientia.*

28.	Hypsiprymnus (υψιπϱυμνος, parte postica elevata). Potoroo.	Did. potoru.
29.	Halmaturus (αλμα, saltus, ȣϱη, cauda). Kangaroo.	Didelphis gigantea, L.

ORDER IV. PRENSICULENTIA.

Family 8. *Macropoda.*

30.	Dipus. Gerboa.	Dipus sagitta, L.
31.	Pedetes (πηδητης, saltator).	D. cafer, L.
32.	Meriones (μεϱος, femur).	D. tamaricinus, L.

Family 9. *Agilia.*

33.	Myoxus. Dormouse.	Myoxus glis, L.
34.	Tamias (ταμιας, promus, condus).	Sciurus striatus, L.
35.	Sciurus. Squirrel.	Sc. vulgaris.
36.	Pteromys. Flying squirrel.	Sc. volans.

Family 10. *Murina.*

37.	Arctomys. Marmot.	Arct. marmota, L.
38.	Cricetus. Hamster.	Mus cricetus, L.
39.	Mus. Rat, mouse.	M. decumanus, L.
40.	Spalax.	M. typhlus, L.
41.	Bathyergus (βαϑυεϱγειν, terram profunde laborare).	M. maritimus, L.

Family 11. *Cunicularia.*

42.	Georichus (γεωϱυχος, qui terram fodit). Mole rat.	M. capensis, L.
43.	Hypudæus (υπȣδαιος, subterraneus). Field-mouse.	M. arvalis, L.
44.	Fiber. Musk beaver.	M. zibethicus, L.

Family 12. *Palmipeda.*

45.	Hydromys.	M. coypus, L.
46.	Castor. Beaver.	Castor fiber, L.

Family 13. *Aculeata.*

47.	Hystrix. Porcupine.	Hystrix cristata, L.
48.	Loncheres (λογχηϱης, qui lanceam fert).	Lonch. paleacea.

Family 14. *Duplicidentata.*

49.	Lepus. Hare.	Lepus timidus, L.
50.	Lagomys. Pica.	L. pusilla, L.

Family 15. *Subungulata.*

51.	Cœlogenys.	Cavia paca.
52.	Dasyprocta (δασυς, hirsutus, πϱωϰτος, anus). Agouti.	C. agouti, L.
53.	Cavia. Guinea-pig, or Cavy.	C. aperea, L.
54.	Hydrochærus. Capybara.	C. capibara.

ORDER V. MULTUNGULA.

Family 16. *Lamnunguia.*

55.	Lipura (λειπουϱος, cui cauda deest).	Hyrax Hudsonius.
56.	Hyrax. Daman.	H. capensis.

Family 17. *Proboscidea.*

57.	Genus Elephas. Elephant. .	E. indicus.

Family 18. *Nasicornia.*

58.	Rhinoceros. . . .	Rh. bicornis.

Family 19. *Obesa.*

59.	Hippopotamus. . .	Hip. amphibius, L.

Family 20. *Nasuta.*

60.	Tapirus. Tapir. . .	T. Americanus.

Family 21. *Setigera.*

61.	Sus. Hog.	Sus scrofa, L.

ORDER VI. SOLIDUNGULA.

Family 22. *Solidungula.*

62.	Equus. Horse, &c. .	E. caballus, L.

ORDER VII. BISULCA.

Family 23. *Tylopoda.*

63.	Camelus. Camel. . .	C. dromedarius, L.
64.	Auchenia (αυχην, collum),	C. llacma, L.

Family 24. *Devexa.*

65.	Camelopardalis. Giraffe.	C. giraffa.

Family 25. *Capreoli.*

66.	Cervus. Deer. . .	C. alces, L.
67.	Moschus. Musk. . .	M. moschiferus, L.

Family 26. *Cavicornia.*

68.	Antilope.	Antilope gnu, L.
69.	Capra. Goat, sheep. .	C. ibex, L.
70.	Bos. Ox.	B. urus, L.

ORDER VIII. TARDIGRADA.

Family 27. *Tardigrada.*

71.	Bradypus. Sloth. . .	B. tridactylus, L.
72.	Chælepus (χωλοιπους, pede claudus). . . .	B. torquatus.
73.	Prochilus (πϱοχειλος, labrosus).	B. ursinus.

ORDER IX. EFFODENTIA.

Family 28. *Cingulata.*

74.	Tolypeutes (τολυπευειν, conglomerare). . .	Dasypus tricinctus, L.
75.	Dasypus. Armadillo. .	D. sexcinctus, L.

Family 29. *Vermilinguia.*

76.	Orycteropus. . . .	Myrmecophaga capensis, L.
77.	Myrmecophaga. Anteater.	M. jubata, L.
78.	... Manis. Pangolin. . .	M. tetradactyla, L.

ORDER X. REPTANTIA.

Family 30. *Reptantia.*

79.	Tachyglossus (ταχυς, velox, γλωσσα, lingua). Echidna.	Myrm. aculeata, Shaw Echidna setosa, Cuv.
80.	Ornithorhynchus. .	Orn. paradoxus.

ORDER XI. VOLITANTIA.

Family 31. *Dermoptera.*

81.	Galeopithecus. Colugo.	Lem. volans. L.

Family 32. *Chiroptera.*

82.	Genus Pteropus. Ternate bat.	Vesp. vampyrus, L.
83.	Harpyia (avis fœda vultu humano mythologiæ).	Vesp. cephalotes, L.
84.	Vespertilio. Bat. . .	Vesp. murinus, L.
85.	Nycteris.	Vesp. hispidus, L.
86.	Rhinolophus, . . .	Vesp. ferrum equum, L.
87.	Phyllostomus, . . .	Vesp. spasma, L.
88.	Noctilio, ...	Vesp. leporinus, L.
89.	Saccopteryx (σακκος, saccus, πτεϱυξ, ala). .	Vesp. lepturus, L.
90.	Dysopes (δυσωπεω, horribili specie perterreo).	Vesp. molossus, L.

ORDER XII. FALCULATA.

Family 33. *Subterranea.*

91.	Erinaceus. Hedgehog.	E. europæus, L.
92.	Centetes (κεντεω, pungo). Tenrec.	E. ecaudatus, L.
93.	Sorex. Shrew. . . .	S. araneus, L.
94.	Mygale. Desman. .	S. moschatus, L.
95.	Condylura (κονδυλος, nodus, ουϱη, cauda). .	S. cristatus, L.
96.	Chrysochloris, . . .	S. auratus, L.
97.	Scalops.	S. aquaticus, L.
98.	Talpa. Mole. . . .	T. europæus, L.

Family 24. *Plantigrada.*

99.	Cercoleptes (κεϱκος, cauda, ληπτης, capiens). Potos.	Viverra caudivolva, L.
100.	Nasica. Coati. . .	V. narica, L.
101.	Procyon. Racoon. .	Ursus lotor, L.
101.	Gulo. Glutton. . .	U. gulo, L.
103.	Meles. Badger. . .	U. meles, L.
104.	Ursus. Bear. . . .	U. arctos, L.

Family 35. *Sanguinaria.*

105.	Megalotis (μεγας, magnus, ους, auris). Fennec.	Canis cerda, L.
106.	Canis. Dog, Wolf. .	C. lupus, L.
107.	Hyæna.	C. hyæna, L.
108.	Felis. Cat. . . .	F. leo, L.
109.	Viverra. Civet. . .	V. zibetha, L.
110.	Ryzæna (ϱυζειν, hirrire ut canis). . . .	V. tetradactyla, L.

Family 36. *Gracilia.*

111.	Herpestes (εϱπηστης, reptans). Ichneumon.	V. ichneumon, L.
112.	Mephitis.	V. putorius, L.
113.	Mustela. Weasel, Martin. . . , . . .	Mustela martes, L.
114.	Lutra. Otter. . .	L. vulgaris, L.

ORDER XIII. PINNIPEDIA.

Family 37. *Pinnipedia.*

115.	Phoca. Seal. . . .	Ph. jubata, L.
116.	Trichechus. Morse.	Tr. rosmarus, L.

ORDER XIV. NATANTIA.

Family 38. *Sirenia.*

117.	Manatus.	Trich. manatus australis, L.
118	Halicore (αλιος, marinus, κοϱη, puella). Dugong.	Trich. dugong, L.
119.	Rytina (ϱυτις, ruga).	Trich. manatus borealis, L.

Family 39. Cete.

120.	Genus Balæna. Whale. . .	B. mysticetus, L.
121.	Ceratodon. Narwhal	Monodon monoceros, L.
122.	Ancylodon (αγκυλος, incurvus, οδους, dens).	
	Anarnak, . . .	Mon. spurius.
123.	Physeter. Cachalot.	Ph. macrocephalus, L.
124.	Delphinus. Dolphin.	D. albicans, L.
125.	Uranodon (ουρανη, palmatum, οδους, dens).	D. butzkopf, L.

The student will not fail to perceive that many of these generic groups, indicated for the first time by Illiger, now form component parts of all our recent arrangements of the animal kingdom.

Although M. Desmarest's work on the Mammalia is one of great value to the student, his system of arrangement so closely resembles that of Baron Cuvier (which, with some modifications, we intend to follow in the present treatise), that its detailed exhibition would be here unnecessary. It bears the date of 1820–22, and certainly presents the most complete and accurate summary of the mammiferous tribes up to that period.[1] It may therefore be assumed as marking an epoch in the science, and as affording a useful point of comparison with preceding times. We have already mentioned that Linnæus was acquainted with not more than about 230 mammiferous animals, and have likewise exhibited the *totals* of his immediate successors. The entire number described by Desmarest is 849, partitioned as follows: Bimana, 1; Quadrumana, 141; Carnivora, 320 (subdivided into Cheiroptera, 97, Insectivora, 29, the true Carnivora, 147, and Marsupialia, 47); Glires, 149; Edentata, 24; Pachyderma, 55; Ruminantia, 97; Cete, 62. But of these 849 species, he marks about 145 with an asterisk, as being too obscurely known to be admitted with certainty to a distinct specific rank. There is also to be deducted 42 fossil species, which leaves 662 as the totality of living mammiferous animals of which we have a distinct knowledge, according to M. Desmarest. In regard to the general distribution of animals over the earth, our author gives the following numerical summary. South America, 181 species; North America, 54; common to Asia and America, 10; Northern Asia, 41; Europe, 88; Africa, 107; Madagascar and Mascareigne, 29; Southern Asia and Ceylon, 78; Indian Archipelago, 51; New Holland and Van Diemen's Land, 33. About 30 cetacea and seals inhabit the northern seas, 14 those of the south, and about 28 the waters of the intermediate regions. The number of terrestrial species subjected to the service of the human race is 13, and out of that limited amount above 112 *varieties* have been produced by the effects of domestication. We may here remark, that from the time of Daubenton (1782)[2] to that of Desmarest (1822), exactly forty years elapsed, and that during that period the amount of known mammiferous animals was more than doubled. During the subsequent fourteen years, we doubt not that the zeal of our other living naturalists has effected a proportional increase.

M. Temminck is chiefly known as a distinguished ornithologist. To an excellent work on certain mammiferous tribes,[3] he has, however, prefixed a "Tableau Methodique" of the orders, genera, and sectional divisions, of the class Mammalia, with an (approximate) enumeration of the species contained in each. He asserts with confidence that these (in 1827) amount to 860 distinct and clearly ascertained kinds. We think it due to a naturalist to whom ornithology, especially that of Europe, stands so highly indebted, to present a view of the system of arrangement in accordance with which he has classed the quadrupeds in the National Museum of the Low Countries (Leyden).

ORDER I. BIMANA.

1. Genus *Homo*, Linn.

ORDER II. QUADRUMANA.

First Tribe. Ancient Continent.

1. *Simia*, Linn. Two species, and a third doubtful.
2. *Hylobates*, Illig. Four species distinctly known, and a fifth doubtful.
3. *Colobus*, Geoff. Two species.
4. *Semnopithecus*, F. Cuvier. Twelve species.
5. *Cercopithecus*, Briss. Composed of two sections, Cercopithecus proper (of which about 20 species), and Macacus (of which 10 species).
6. *Innuus*, Geoff. One species.
7. *Cynocephalus*, Briss. Nine species.

Second Tribe. New Continent.

8. *Mycetes*, Illig. Six distinct species, and one doubtful.
9. *Ateles*, Geoff.
10. *Cebus*, Erxleb. Amount difficult to determine, from confusion in synonymes, and variation in age and sex.
11. *Pithecia*, Geoff. Six or seven species.
12. *Lagothrix*, Geoff. Two species.
13. *Callithrix*, Cuv. Eight species.
14. *Hapale*, Illig. Fifteen or sixteen species.
15. *Nocthora*, F. Cuv. Three species.

Third Tribe. Lemuridæ.

16. *Otolicnus*, Illig. Three species ascertained.
17. *Tarsius*, Storr. One species.
18. *Stenops*, Illig. Five species.
19. *Lichanotes*, Illig. One species.
20. *Lemur*. Twelve species.
21. *Galeopithecus*. Two species.

ORDER III. CHEIROPTERA.

1. *Dysopes*, Illig. Eleven species known, and eight others indicated, besides a European species still obscure.
2. *Pteropus*, Briss. Seventeen species, of which one is probably nominal.
3. *Cephalotes*, Geoff. Two species.
4. *Stenoderma*, Geoff. One species.
5. *Mormoops*, Leach. One species.
6. *Noctilio*, Geoff. One species.
7. *Phyllostoma*, Geoff. Eleven or twelve species.
8. *Vampirus*, Geoff. Two or three species, of which only one is well determined.
9. *Glossophaga*, Geoff. Six species.
10. *Megaderma*, Geoff. Three species.
11. *Rhinolophus*, Geoff. Fourteen known and two doubtful species.
12. *Nycteris*, Geoff. Three species, of which one is rather doubtful.
13. *Rhinopoma*, Geoff. One species.
14. *Taphozous*, Geoff. Seven species.
15. *Emballonura*, Kuhl. Two species, and a third doubtful.
16. *Nycticejus*, Rafinesque. Eight species.
17. *Vespertilio*, Linn. Probably forty species, or upwards.

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[1] *Mammalogie, ou description des espèces de Mammifères.*

[2] *Dictionnaire des Quadrupèdes de l'Encyclopédie.*

[3] *Monographies de Mammalogie.*

Order IV. Carnivora.

First Tribe. Insectivora.

1. Genus *Erinaceus*, Linn. Two well known species, and a third doubtful.
2. *Sorex*, Linn. Fourteen or fifteen species.
3. *Hylogale*, Temm. Three species.
4. *Mygale*, Cuv. Two species, and a third doubtful.
5. *Scalops*, Cuv. One or two species.
6. *Chrysochloris*, Cuv. One well known species.
7. *Condylura*, Illig. One or two species.
8. *Talpa*, Linn. Three species.
9. *Centetes*, Illig. Three species.

Second Tribe. Carnivora proper.

10. *Ursus*, Linn. Ten or eleven probably distinct species.
11. *Procyon*, Storr. Two species.
12. *Nasua*, Storr. Two species.
13. *Cercoleptes*, Illig. One species.
14. *Taxus*, Linn. Two species.
15. *Mydaus*, F. Cuv. Two species.
16. *Gulo*, Retsi. Five or more species, some of which but ill determined.
17. *Arctictis*, Temm. One species.
18. *Paradoxurus*, F. Cuv. Six species.
19. *Mustela*, Linn. Twenty species ascertained, and others indicated.
20. *Lutra*, Briss. Six species.
21. *Mephitis*, Linn. Two species.
22. *Herpestes*, Illig. Eleven species.
23. *Ryzæna*, Illig. One species.
24. *Viverra*, Linn. Nine species known, and two more indicated.
25. *Canis*, Linn. Thirty species known, and several others indicated.
26. *Proteles*, J. Geoff. One species.
27. *Hyæna*, Briss. Two well known species, and a third indicated.
28. *Felis*, Linn. About thirty species known, besides several others not yet distinctly constituted.

Third Tribe. Amphibia.

29. *Phoca*, Linn. Fourteen or fifteen species known, besides a few which are doubtful.
30. *Otaria*, Peron. Six species, one of which is doubtful.
31. *Trichechus*, Linn. One species.

Order V. Marsupialia.

1. *Didelphis*, Linn. Twelve well known species, and three doubtful.
2. *Cheironectes*, Illig. One species.
3. *Phascogale*, Temm. Two species.
4. *Thylacinus*, Temm. One species.
5. *Dasyurus*, Geoff. Four species.
6. *Perameles*, Geoff. Two species.
7. *Phalangista*, Geoff. Eight species.
8. *Petaurus*, Shaw. Five species.
9. *Hypsiprymnus*, Illig. Two or three species.
10. *Halmaturus*, Illig. Eight species.
11. *Phascolarctos*, Blainv. One species.
12. *Phascolomys*, Geoff. One species.

Order VI. Glires.

1. *Castor*, Linn. Two species.
2. *Fiber*, Cuv. One species.
3. Genus *Hypudæus*, Illig. Amount doubtful.
4. *Lemmus*, Cuv. Probably eight species, three doubtful.
5. *Spalax*, Gulden. Probably three species.
6. *Echimys*, Geoff. Eight species.
7. *Myoxus*, Gmel. Six species.
8. *Myopotamus*, Commers. One species.
9. *Hydromys*, Geoff. Two species.
10. *Capromys*, Desmar. One species ascertained, another doubtful.
11. *Mus*, Linn. A numerous, badly arranged, and obscurely determined genus, of which the amount may be stated approximately at about forty species.
12. *Ascomys*, Lichten. One species.
13. *Bathiergus*, Illig. Two species.
14. *Pedetes*, Illig. One species.
15. *Dipus*, Gmel. Seven species, of which probably a few are merely nominal.
16. *Meriones*, Illig. Five or six species, besides those indicated by M. Rafinesque.
17. *Aulacodus*, Swind. One species.
18. *Arctomys*, Linn. Four well known species, and a like number doubtful.
19. *Spermophilus*, F. Cuv. Five species.
20. *Sciurus*, Linn. About thirty established species, and from eight to ten of doubtful indication.
21. *Pteromys*, Cuv. Eight well known species.
22. *Cheiromys*, Cuv. One species.
23. *Hystrix*, Briss. Four established species, and one doubtful.
24. *Sinœtherus*, F. Cuv. Two well determined species, and a third probable.
25. *Lepus*, Linn. Twelve species.
26. *Lagomys*, Geoff. Three species.
27. *Hydrochærus*, Briss. One species.
28. *Cavia*, Erxleb. Three species.
29. *Dasyprocta*, Illig. Four or five species.
30. *Cœlogenus*, F. Cuv. Two species.

Order VII. Edentata.

1. *Bradypus*, Linn. Three species.
2. *Dasypus*, Linn. Eight species, of which two are more or less doubtful.
3. *Orycteropus*, Geoff. One species.
4. *Myrmecophaga*, Linn. Four species, and two others of which the existence is probable.
5. *Manis*, Linn. Three species.

Order VIII. Pachydermata.

1. *Elephas*, Linn. Two species.
2. *Hippopotamus*, Linn. One species.
3. *Phascochæres*, F. Cuv. Probably two species.
4. *Sus*, Linn. About six species.
5. *Dicotyles*, Cuv. Two species.
6. *Rhinoceros*, Linn. Four or five species.
7. *Hyrax*, Herman. One species.
8. *Tapyrus*, Briss. Two species, and a third obscurely known.
9. *Equus*, Linn. Seven species.

Order IX. Ruminantia.

First Tribe. Without Horns.

1. *Camelus*, Linn. Two species.
2. *Auchenia*, Illig. Three species.
3. *Moschus*, Linn. Five species, one of which is doubtful.

Second Tribe. The Males Horned.

4. Genus *Cervus*, Linn. About twenty-four species known, besides a few others which are doubtful.

Third Tribe. Horns encased.

5. *Camelopardalis*. One species.
6. *Antilope*, Pallas. Between forty and fifty species are distinctly known, and there are indications of five or six other species.
7. *Catoblepas*, Ælien. Two species.
8. *Capra*, Linn. Five or six typical species, with numerous varieties.
9. *Ovis*, Linn. Six or seven distinct species, with numerous domestic races.
10. *Bos*, Linn. Nine distinct species, and many domestic varieties.

Order X. Cetacea.

First Tribe. Herbivora.

1. *Manatus*, Linn. Two species, and a third doubtful.
2. *Halicore*, Illig. One species.
3. *Stellerus*, Cuv. One species.

Second Tribe. Piscivora.

4. *Delphinus*, Linn. Fifteen or sixteen species are pretty accurately known, and about fourteen others are indicated, many of which are no doubt purely nominal.
5. *Monodon*, Linn. One well known species, and two or three others obscurely, and probably inaccurately indicated.
6. *Physeter*, Linn. Two species, better known than five or six others of which we have only vague indications.
7. *Balæna*, Linn. Only four or five species have been tolerably described, and even of these some are doubtful. Many others have been named, of the majority of which, however, the existence is as yet conjectural.

Order XI. Monotrema.

1. *Echidna*, Cuv. One species.
2. *Ornithorhynchus*, Blumenb. Two species.

The student will bear in mind that the preceding methodical abstract bears the date of 1827, and that several important additions, and a few corrections, have been made by various naturalists since that period. It presents, however, upon the whole, an accurate and ample view.[1]

General characteristics.

In the article Animal Kingdom of the present work,[2] we have endeavoured to sketch the general attributes and co-relations of the great primary divisions of the subjects of zoological science, and we shall not here repeat our statements. The class Mammalia on which we are now about to enter, stands at the head of that first great division of the animal kingdom, which, by reason of the brain and continuous lengthened mass of the nervous system being contained within the bony envelope of the cranium and vertebræ, is named the vertebrated division, and of course comprises all the higher classes, or *animalia vertebrata*. These are,—Mammalia, birds, reptiles, and fishes, the last of which alone, under the term Ichthyology, have as yet been illustrated in our present work.

The Mammalia in the system of Baron Cuvier, and indeed of all the other systematic writers (although Lamarck, guided by peculiar views regarding the *progressive* development of species, follows an inverse order), are placed at the head of the animal kingdom,—not only because they form the class to which we ourselves belong, but because they are endowed with the highest combination of faculties, the most delicate sensations, and the most varied movements. There certainly results from the totality of their physical qualities, an intelligence more perfect, and fertile in resources, less enslaved to the blind impulses of instinct, and consequently more capable of amelioration and improvement, than that of the other vertebrated tribes.

As their power or amount of respiration is moderate compared to that of birds, the great majority are formed for walking on the surface of the earth, or for certain motions dependent for support on bodies connected with that surface. The articulations of their bones have consequently precise forms which determine their movements, and even circumscribe them with rigour. Certain species, however, possess the power of raising themselves into the air by means of prolonged and extended membranes, with which their limbs are furnished; while others have those limbs so shortened and concealed beneath the teguments, as to render them incapable of progressive movement except in water; but, nevertheless, though fish-like in their forms, they in no way lose the characteristics of their class, and the unwieldy whale is as truly a warm-blooded mammiferous animal as the most active of monkeys.

In all Mammalia the upper jaw is fixed to the cranium, and the under one, composed of only two portions, articulates by means of a projecting condyle to a fixed temporal bone. The cervical vertebræ, as already mentioned, are seven in number. The anterior ribs are attached forwards by cartilaginous pieces to a sternum, formed of a certain number of vertical portions. The anterior extremities commence from a shoulder-blade, not articulated, but merely suspended in the flesh, and often supported on the sternum by an intermediate bone, named the clavicle. These extremities are further composed of an arm (*humerus*), a fore-arm (*radius* and *cubitus*[3]), and a hand,—the last named

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[1] We do not here enter into the vexed question of the quinary or other circular systems of arrangement, as these are as yet somewhat too much connected with critical asperities, and have scarcely in themselves subsided into a lucid or tranquil element of science. We do not think our readers would have benefited by our adopting any of the so-called natural systems as the basis of the present article. We should not, however, hold ourselves excused were we not to advert with respect and gratitude to those who have, with various degrees of success, endeavoured to establish that system. In relation more particularly to our present subject, we had with some care prepared an abstract of Mr Swainson's views of the natural classification of Mammalia, but we now think that more justice will be done the enlightened author (and assuredly more advantage will accrue to the attentive reader) by his arrangement being taken rather in connection with the many interesting and valuable observations by which it is explained and supported, than in such disjoined and compendious form as would suit our present limits. It is indeed one of the disadvantages of such systems, that their merits cannot be fairly exhibited *linearly*, nor done justice to in any ordinary form of tabular exposition. We therefore earnestly advise the student to a very careful perusal of Mr Swainson's *Zoological Illustrations*, and of his papers, which he will find published in Dr Lardner's *Cyclopædia*. They ought to be in the hands (and heads) of every naturalist, and their unassuming form and moderate price fortunately render them accessible to all classes of the community.

[2] Vol. iii., p. 168.

[3] These two bones of the fore-arm are sometimes distinct, and capable of a certain oblique rotation on each other (as in man and monkeys); or they are fixed by their extremities (as among the majority of the *Feræ* and *Rodentia*). Sometimes the radius becomes the principal bone, and the cubitus, reduced to a rudimentary state, forms only a simple apophysis. This is the case among ruminating animals, and the genus *Equus* or horse tribe.

General characteristics.

being itself constituted by two ranges of small bones named *metacarpus*, and of fingers or *phalanges*. The extremities of these last bear the nails or hoofs. With the exception of the Cetacea, all the species have the first portion of the posterior extremities attached to the spine, and forming a girdle or pelvis, which in early age, is divisible into three pairs of bones, the *ilium*, which is attached to the spine; the *pubis*, which forms the anterior girdle; and the *ischium*, which forms the posterior. At the point of the union of these three bones is the cavity which contains the articulation of the thigh (or *femur*), to which is attached the leg, itself composed of two bones, the *tibia* or shin bone, and the *fibula*.[1] The leg is terminated by the foot, a compound organ, composed of parts analogous to those of the hand, and named the *tarsus*, the *metatarsus*, and the toes.

The head in the Mammalia is always articulated by two condyles on the atlas or first vertebral joint. The brain is always composed of two hemispheres united by a medullary lamina called the *corpus callosum*, containing two ventricles, and inclosing four pair of tubercles called the *corpora striata*, the *optic thalami*, the *nates*, and *testes*. Between the optic thalami there is a third ventricle, which communicates with a fourth placed beneath the cerebellum. The crura of the cerebellum always form beneath the medulla oblongata a transverse prominence called the *pons Varolii*.

The eye, lodged within its orbit, is protected by two eyelids, and the vestige of a third. Its crystalline humour is fixed by the ciliary processes, and the sclerotic coat is simply cellular.

In the ear of the Mammalia there always exists a cavity called the drum (*cavitas tympani*), which communicates with the *pharynx*, by means of a canal called the *eustachian tube*, and is closed externally by the *membrana tympani*. This cavity contains four small bones known as the *incus* or anvil, the *malleus* or hammer, the *stapes* or stirrup, and the *os orbiculare* or spheroid bone. The ear is further composed of the *vestibule*, at the entrance of which is placed the stapes, and which communicates with three semicircular canals, and of the volute or *cochlea*, which terminates by one of its scalæ in the tympanum, by the other in the vestibule.

The cranium may be said to be composed of three compartments:—the anterior formed by the two frontal bones and the ethmoid, the intermediate by the parietal bones, and the sphenoid, and the posterior by the occipital. Between the occipital bones, the parietals, and the sphenoid, are inserted the temporal bones, a portion of which belong, properly speaking, to the face. In the fœtal condition these bones exhibit various subdivisions, still more numerous in the embryo state, and become more and more compact and simple in the adult animal.

The face is formed essentially of the two maxillary bones, between which passes the nasal canal; these bones have in front the two intermaxillaries (which bear the incisive teeth), and behind them the two palatines, while between them descends the single lamina of the ethmoid named the *vomer*. On the openings of the nasal canal are the proper bones of the nose. The jugal or cheek bone unites on each side the maxillary to the temporal, and often to the frontal bone; and finally, the lachrymal occupies the internal angle of the orbit, and sometimes a part of the cheek.

The tongue is always fleshy, and attached to a bone called the hyoid, suspended by ligaments to the cranium.

The lungs, two in number, are subdivided into lobes composed of an infinity of little cells, and are always inclosed without adhesion in a cavity formed by the ribs and diaphragm, and lined by the pleura. The organ of the voice is always at the upper extremity of the tracheal artery or windpipe, and a fleshy prolongation called the *velum palati* or soft palate, establishes a direct communication between the larynx and back of the nostrils.[2]

General characteristics.

Dwelling habitually on the surface of the earth, mammiferous animals are less exposed than certain other classes to extreme alternations of heat and cold, their covering or hair is of moderate thickness, and is usually of a slighter texture in the species of warmer climes. Linnæus, the nature of whose genius led him to seek for the establishment of a kind of distinctive opposition in the characters of animals, maintained, among other generalised dicta, that Mammalia were furnished with hairs, birds with feathers, and fishes with scales. This is true in a general sense, although the Cetacea, which dwell exclusively in the water, are destitute of any hairy covering, and the pangolins and other species seem covered with scales. Blainville, indeed, is of opinion that the usual hairy coating exists, though under another aspect, equally among whales as in ordinary quadrupeds, and the distinction presented by the scaly species of land animals is more apparent than real. Yet as many birds are also partially covered by what does not essentially differ from hair, we do not think that the name of *Piliferes*, by which M. de Blainville desires to designate all mammiferous animals, is in any way preferable to that derived from their functions of maternity. Quadrupeds have usually two kinds of covering intermingled,—the hairy, which is of a more or less stiff or consistent texture (varying as it were from *silk* to *bristle*), and from its greater length is the more apparent and external,—and the woolly, which is extremely soft and fine, and is usually concealed beneath the other. The domestic races of the sheep, however, form a remarkable and highly beneficial exception to the contrary, in the great length and abundance of the woolly portion, and the almost total disappearance of the silken or hairy. There is also an approach to this character in most animals belonging to cold countries, while in those of tropical regions the silky coat becomes much developed, and the woolly diminishes or disappears. The quantity or proportional abundance of wool is usually in an inverse ratio, that of silk in a direct ratio, to the temperature. The silky coat or hair, is of great length on particular portions of several species, such as the mane of the lion and the horse, and the tail of the latter; and a species of Indian bear (*Ursus labiatus*) is remarkable for the length of its hair, which measures from seven to nine inches over the general surface, and on particular spots is nearly a foot long.

In some species the covering is partially or even entirely composed of spiny projections, varying in form and aspect; such as those of the hedgehog, tanrec, echimys, porcupine, and others. All these spines are usually pointed and cylindrical, and bear the form of a gigantic hair. But in the common porcupine (*Hystrix cristata*) the tail is garnished with cylindrical tunnels, which are open transversely at their extremity, thus resembling quills which have been cut across at the commencement of their opaque portion. In all the spiny species naturalists have remarked that there is a great development of those muscles which act upon the skin, a condition, in truth, indispensable in rendering the spines effective as weapons of defence.

The colours of mammiferous animals are in general much less brilliant than those of several other classes, and are almost entirely destitute of that metallic splendour

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[1] These two last-named bones offer the same variations in their relation to each other, as do those of the fore-arm just noted.

[2] *Règne Animal*, t. i., pp. 60-63. For details of internal structure, the general reader is referred to the article COMPARATIVE ANATOMY of this Encyclopædia, vol. iii., p. 74; to the writings of Camper; or to the Sketch prefixed by M. Desmarest to his *Mammalogie*. The professional student will seek the more laboured systems of Cuvier, Meckel, De Blainville, Carus, or the excellent *Outlines* by Dr Grant, and the admirable Dissertations of Professor Owen.

General characteristics.

which so enriches the livery of the feathered tribes. In this particular the Chrysochlore, a small insectivorous animal from Africa, allied to the mole, forms almost the sole exception. Another general characteristic of the coat of the Mammalia consists in the colours being much paler over the lower surface than on the flanks or dorsal regions. This observation applies not only to the ordinary quadrupedal form, in which the under surface is less exposed to view, but to the kangaroos and other leaping kinds, in which from the almost vertical position of the body, the abdomen and the back are equally open to the influence of light and air. The exceptions are of two kinds, 1st, of animals like the polar bear, which are of one uniform colour throughout; and, 2dly, of certain other species like the glutton, ratel, and badger, which are lighter above than below. Of this one of the most remarkable examples is furnished by an Indian animal called Panda (*Ailurus refulgens*), which is of a beautiful cinnamon red colour above, with the abdomen of the deepest black.

The colours of quadrupeds are sometimes mottled or closely intermingled,—an effect produced by each hair being composed of rings of different hues, as in most of the squirrels; sometimes these colours are more broadly varied, or in stronger contrast, as among the larger spotted cats or feline animals; but in the majority of quadrupeds the colours of each species are rather uniform than varied, although the *Makis* and others exhibit some strongly contrasted markings. The sexual distinctions, as derived from the external covering, are much less remarkable than among the feathered tribes, the female being for the most part only somewhat less vivid than the male. Neither does the progressive advancement to age from adolescence manifest changes so singular and extensive as those of birds, although among several species, such as stags, lions, and others, the colours in early life are differently disposed from what they are in the adult condition. The young fawn is spotted with white, an aspect which is permanent in that species of deer called axis, while young lions are variously marked with dark brown or black, thus resembling the matured condition of many of their congeners. This remarkable relation between the colouring of *young* individuals of one species, and that of other species of the same genus in the *adult* state, is likewise observable in birds, but with this difference, that the early plumage, usually resembling that of the female, is always more dingy and obscure than that of the adult, whereas, as already hinted, the covering of the young Mammalia is frequently more elegantly varied than that of their parents. The varieties of colour among domesticated animals are too numerous to be here detailed, and indeed too familiar to require illustration. Even among unreclaimed species frequent varieties occur, and moles and many other animals are found of a white or cream-colour. These changes have been observed to be extremely uncommon among the cheiropterous species, or bats. The term *albinism* is applied to the condition of the white varieties, that of *melanism* to that of the black ones; the former being more frequent in cold countries, the latter in warm ones. But melanism is much rarer than albinism, and has hitherto been observed chiefly among feline animals, deer, and rats. The water-rat, commonly so called (*Arvicola amphibia*), frequently occurs exclusively of a black colour, over a whole district of country. It has not yet been demonstrated as a distinct species, though by some regarded as such.

Besides the diseased or accidental condition of albinism, several species, such as hares, ermines, and foxes, become annually white in northern countries, during the winter season. Black seems the colour most persistent in these animals throughout the year; thus the ermine always preserves the black extremity of the tail, and the points of the ears are at all times of that colour in the Alpine hare. The same fact is exemplified among birds of the ptarmigan tribe. It is difficult, however, to determine distinctly whether these and other analogous changes are the direct result of cold, as the immediate cause, or belong to some other chain of providential facts by which the well-being of these creatures is sedulously guarded amid those inclement countries in which they have been doomed to dwell. At least we know that among birds we have numerous species with plumage of the purest white inhabiting the most sultry of the tropical regions, while the ominous raven, with a covering as usual of the deepest black, is one of the few species which braves the intensity of a polar winter, and is seen, or rather heard, throughout that long-enduring night, croaking among the desolate cliffs, or gliding like the spirit of evil along the barren ice-bound shores.

General characteristics.

Although the subject has not been investigated in detail, we know in a general way that albinism is produced by debilitating causes, and results from the absence of the colouring matter of the skin; and if, on the other hand, it could be demonstrated that melanism is rather the result of fortifying causes, and of a superabundance of the colouring material, we should then more clearly perceive how it happens that all species, whatever may be their natural hue, are liable to exhibit one or other of the phenomena in question.

Prehension, or the seizing and handling of their food, or other substances, is executed among carnivorous and gnawing animals (Feræ and Rodentia) by means of the toes, which are usually very distinct, and terminated by nails or claws more or less pointed. In some species, such as the squirrels among the Rodentia, and the racoons among the carnivorous kinds, the food is held by a kind of pressure between the two anterior paws, and carried upwards to the mouth. The hand of man is a much admired instrument, and more perfect in its way, although of the same general structure, than that of monkeys and other quadrumana; which, however (with the exception of the genus *Ateles*), possess an advantage over us in the opposable nature of the great toe, by which they are rendered equally expert with either extremity. They are, in truth, as the name imports, four-handed, and are consequently the most accomplished of climbers, as we may easily conceive, by imagining with what activity, in spite of his comparatively heavy form, a sailor would ascend the shrouds, or reef the sails, if his feet were so constructed as to grasp as firmly as his hands.

The toes in quadrupeds never exceed five in number, and have never more than three articulations: there are sometimes only two articulations, and the number of toes frequently differs on the anterior and posterior extremities. These parts have furnished excellent characters for classification, when not assumed as the sole and exclusive basis of arrangement. Thus Klein, the Königsberg naturalist, divided animals into orders and sections according to the form and number of the toes, thereby bringing into juxtaposition many species entirely dissimilar to each other, and at the same time separating others between which there existed the strongest natural alliance; while Linnæus, with his wonted sagacity, deduced from the toes only generic characters, subordinate to the more important parts of the organization, and thereby rendered them available in systematic arrangement. In many species, especially the feline, the toes are furnished with sharp, curved, retractile talons, which become very formidable weapons of defence or attack. In man, and the different species of monkeys, they are possessed of great discrimination in the sense of touch, and a false or at least exaggerated view of the subject has led Helvetius and others to attach an extraordinary degree of importance to the *hand*, as the medium of intellectual superiority in the human race. In bats the anterior toes assume a singular form, become greatly extended, and having their interstices filled up by membranes, act in the capacity

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of wings; while in seals, walruses, and cetaceous animals, such as whales, they pass by different gradations into the form of fins.

The prehensile power of the Mammalia is not, however, confined to their feet and hands. Many of the American monkeys make use of their tails, both in locomotion and for the seizure of their food; and the kinkajou is said to insert the tip of that portion of its body into holes in which crustacea lie concealed, and which seizing upon and pertinaciously adhering to the intruding organ, are speedily dragged from their concealment and devoured. But the proboscis of the elephant, terminated by a strong opposable appendage, is one of the most perfect prehensile instruments to be found within the range of the animal kingdom. The same mode of seizure, but with a more restricted action, is practised by the great tribes of ruminating quadrupeds, which, using their limbs only as organs of support and locomotion, collect their food by means of the mouth alone, that is, by a combined action of the lips, teeth, and tongue.

We need scarcely observe, that all mammiferous animals are viviparous, that is, produce their young alive, and, consequently, as their name implies, nourish them by means of the secretion named milk. This brings us round to the definition with which we started, and we shall now proceed to a short exposition of the orders of the class Mammalia, as established and defined by Baron Cuvier.

The variable characters which establish the most essential differences among mammiferous animals are derived from the organs of touch, on which depend their greater or less degree of ability and address, and from the organs of manducation, which determine the nature of their aliments, and regulate not only all that relates to the digestive functions, but also a cloud of other characteristics intimately connected with their habitual instincts. The perfection of the organs of touch may usually be estimated according to the number and mobility of the toes (using the word in its more enlarged acceptation as including the terminal portions of both the fore and hind extremities), and the mode and degree in which these parts are enveloped within the claws or hoofs. A hoof which entirely encompasses all that portion of the toes which touches the ground, of course not only blunts its feeling, but renders it incapable of grasping. The opposite extreme consists in a simple flattened nail, which covers only a limited terminal portion of the toes, and leaves the remainder in a state of delicate perception.

The habit of life in regard to food or regimen may be accurately inferred from the cheek-teeth, with the form of which the articulation of the jaws is always found to correspond. For the purpose of cutting flesh, these cheek-teeth (commonly called grinders in the herbivorous animals) are in the carnivorous kinds trenchant like a saw or scissars, and the jaws are so restricted in their movements as to be incapable of lateral or horizontal motion, and meet each other vertically, with a firm but circumscribed action. On the other hand, animals destined to live by the mastication of grain or herbs have flat-crowned cheek-teeth, placed in jaws capable of horizontal motion; and as it is desirable that the upper surface of such teeth should preserve a certain inequality, like that of a mill-stone, they are found to be composed of portions of unequal hardness, one of which wears quicker than the other. All hoofed animals are of necessity herbivorous, and provided with flat-crowned grinders, because their feet are incapable of seizing a living prey. But unguiculated animals exhibit a greater variety of form and diet, and differ greatly among themselves, not only in the structure of their teeth, but also in the mobility and perceptive powers of their toes. One special character in this respect, which has prodigious influence on the general address of animals, by multiplying their means of prehensile action. is the faculty before alluded to of opposing the thumb to the other fingers, so as to constitute a hand fitted for the secure and delicate seizure of the smallest objects. These various combinations, which in truth determine with great rigour the nature of the mammiferous tribes, have occasioned the establishment of the following orders:—

Characters of the Orders.

Among the unguiculated animals, commonly so called, the first is man, a privileged being, who enjoys a multiplicity of advantages over all other sublunary creatures, but who, in the technical language of zoology, is characterized by his erect position, and the possession of hands to his anterior extremities only. These, of course, are the accidents, not the essentials of his nature, and are inadequate to the description of a being who bears within him the germ of an immortal life. It is indeed the usual practice of naturalists to begin their systematic exposition of the animal kingdom with a "Nosce teipsum," followed by a sketch of the physical attributes of the human race, as if that race were undistinguished by a lofty and spiritual existence, by an independent and superior perception, entirely different in its essence and action from the nature of the external senses. We have previously reclaimed against this preposterous classification of Man, of him who was created "but a little lower than the angels," with the brutes that perish, and we shall not here depart from our accustomed rule, further than to mention that in Baron Cuvier's system, by which in other points we shall be mainly guided, the human race is regarded as the first order, and is named BIMANA, from the peculiarity above alluded to.

The next order (and it is that with which we shall commence our systematic exposition), is distinguished by what are regarded as hands on both the fore and hind extremities, and is hence named QUADRUMANA.

Then follows a great group which possess no free or opposable thumb on either the fore or hind extremities: these are the carnivorous animals, or order FERÆ.

In all the preceding orders we find three different kinds of teeth, viz. the molar or grinding-teeth, which are better named cheek-teeth, seeing that their function in carnivorous animals is rather to cut than to grind; the canine teeth; and the incisive teeth.

The groups which compose Cuvier's fourth order do not differ essentially in the nature of their extremities from the ferine order, but they want the canine teeth, and have incisives in front of the mouth, so disposed as to fit them admirably for that kind of manducation called gnawing. Hence they constitute the *Rongeurs* of the French naturalists—the order GLIRES or RODENTIA.

Following these we have certain kinds of which the toes are straitened and sunk within great claws, usually curved, and which moreover want the incisive teeth. In some even the canine teeth are absent, while a few are entirely deprived of those organs. They are all comprehended under the order EDENTATA.

The preceding orders are all unguiculated, that is, provided with nailed toes, capable of distinct and articulate movement. These, though still existent, become constrained and encrusted within a callous skin in the ensuing order, and decrease in number till in the solipedal family, corresponding to the genus *Equus* of Linn. (the horse tribe), there is only one apparent toe, covered by a single undivided hoof, on each foot. These groups constitute the order PACHYDERMA, so named from the usual thickness of their skins.

The other hoofed genera compose a very distinct group, distinguished by their cloven feet, the absence of true incisives in the upper jaw, and their quadruple stomachs. From certain peculiar functions of the last named organs they are named ruminating animals.—order PECORA.

Finally, there are several aquatic Mammalia, of which the posterior extremities assume the form and functions of a tail, while the anterior members act as fins. These are the gigantic whales and rolling porpoises, which, with others not necessary to be here named, constitute the great concluding order called CETACEA.

Probably the most objectionable part of the preceding system consists in placing all the pouched or marsupial animals (kangaroos, &c.) as the terminal portion of the carnivorous order. These creatures consist, in truth, of various groups, possessed of few characters in common, and ought no doubt to be distributed through several different orders, instead of being brought together (merely in consequence of each being characterized by the possession of a *marsupium* or pouch) as a ferine family, under the name of *Marsupialia*. Their creation into a distinct order, as by some proposed, is for the same reasons equally objectionable.

Although in the present treatise we follow the system of Baron Cuvier's "Règne Animal," rather than that of any more modern, or, it may be, amended classification, we shall yet be careful to introduce from time to time such observations of contemporary naturalists as may seem to us to be in any way truly corrective of that system. We think, indeed, that there may possibly be some misconception on the part of many modern writers, who, deriving almost all of what they essentially know from the labours of the great French anatomist, and obviously and almost confessedly hanging their own restricted and superficial observations on the gigantic trunk which he had already raised (and which centuries will fail to undermine), suppose that because a few glittering leaves or even "bright consummate flowers" of their own imagining may sometimes meet the view, that they have *created a system!* Now, the actual truth may rather be, that had not the system itself been previously prepared for them, and so much transparent light called forth from such a depth of darkness, they might as easily have found their way in absence of the sun through tangled woods or pathless deserts, as have by actual observation or any intellectual effort of their own, ascertained the existence of a single great principle in natural history. But be this as it may; we have already presented the reader with tabular views of the prevailing modern systems, and these he may study and compare together, and with that which follows, and draw his own conclusions. This process will assuredly be to his, if not to their advantage.

ORDER I.—QUADRUMANA.

QUADRUMANOUS, OR FOUR-HANDED ANIMALS.

Teeth of three sorts—incisive, canine, and molar. Each of the four extremities furnished with a thumb, free in its movements, and capable of being opposed to the other fingers or toes, which are long and flexible, and bear a strong resemblance to the fingers of the human hand. The eyes are directed forwards. The mammæ, which are pectoral, vary in number from two to four. A bony partition separates the temporal cavities from the orbits; but the nasal bone does not exhibit the suture observable in that of man. The stomach is simple and membranous, and the intestines are short, and greatly resemble those of the human race.

The animals of this varied and extensive order, familiarly known under the names of orang, ape, monkey, &c. inhabit the warmer regions of Asia, Africa, and America. A single species remains as a European representative on the rock of Gibraltar, either by descent as an indigenous animal, or by accidental importation from the opposing coast of Barbary, where it is extremely frequent. The quadrumanous order dwells almost exclusively in woods, feeding in general on fruits, roots, grain, and other vegetable produce. A passage, however, occurs in Ogilby's Translation of Niewhoff's China, which, probably more remarkable for graphic effect than accuracy, assigns a very different disposition to some large species of the order. "The province of Fokien hath an animal perfectly resembling man, but longer armed, and hairy all over, called *Fese*, most swift and greedy after human flesh; which, that he may the better take his prey, *he feigneth a laughter*, and suddenly, while the person stands listening, seizeth upon him."[1] The propensity of several of the smaller species to feed on eggs and insects is better ascertained.

The most remarkable characteristic of their external form is the extraordinary resemblance which many of them bear to the human race; and their internal structure offers equally striking analogies. Their distinctive character, however, is by no means difficult to seize;—their posterior extremities, naturally unfit for the assumption of an erect position, are admirably adapted for prehension, and the species are consequently the most active in their *arboreal* habits of all the larger animals. The opposable thumb on all the four extremities, although a leading character in the great majority of the order, and the one from which the ordinal name is itself derived, cannot strictly be said to occur in all the genera. In truth, it is ever thus with any *single* character, however influential, which naturalists may choose to select as the basis of any great natural group. A combination with other features is usually required, otherwise the organ selected will be found to undergo so many modifications, as not seldom to evade or contradict the definition. Thus in the monkey tribe the genera *Ateles* and *Colobus* want the thumb to the anterior hands, and in several of the *Semnopitheci* it is merely rudimentary. These therefore can scarcely be called *quadrumanous*, if we take the term in its strictest etymological acceptation. It has been remarked as a fact worthy of attention, that the anomalies by which many quadrumanous animals depart, as it were, from their characteristic type of form, affect the anterior rather than the posterior members. In man, the anterior extremities alone have a free and opposable thumb. Among the Quadrumana, on the contrary, the so called thumb exists constantly on the posterior members, in a well developed state, but is frequently absent or rudimentary on the anterior extremities. Even among marsupial species we frequently find a free thumb on the hind feet, but never on the anterior, and the like structure is observable in a peculiar animal, usually ranged near the squirrels, the *Cheiromys Madagascariensis*. Thus it appears that various animals possess a true, that is, opposable thumb, on the hind feet, which do not possess it on the fore ones, and that the inverse character occurs only in a single creature, of which the reader and writer of the present article afford examples.

The quadrumanous order of animals certainly holds a high rank in the animal kingdom; but, though apes and monkeys often astonish us by their apparent power of imitating the actions of men, we agree with Buffon in thinking that they are not in a corresponding degree superior to other brute animals which do not possess that power. The talent, in fact, does exist in many species, but is necessarily (from their structure) confined to the imitation of their own kind; but the ape, though he does not belong to the human race, copies many of our actions (and unavoidably) through the resemblance of his organization. Thus what most have ascribed to superior intelligence, is nothing but the result of a gross affinity of form and figure.

In accordance with the modern arrangements, our pre-

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[1] Second edition, p. 413.

Quadrumana.

sent order is divisible into two extensive families, the Simiadæ and Lemuridæ, groups corresponding in a great measure to the old genera *Simia* and *Lemur* of Linn.

FAMILY I.—SIMIADÆ, Apes in general.

These, in their ordinary form and aspect, more or less resemble man. They have four straight incisive teeth in each jaw, and all their nails are flat. Their molar or cheek teeth, like those of man, are bluntly tuberculated, and in their habits of life they are essentially frugivorous, although their appetites, like our own, seem very accommodating. Their canine teeth, however, exceed the others in length, and often require for their points a corresponding lodgement in the opposing jaw. The family is further divisible into two minor groups.

1st Sub-Family.—Simiæ Catarrhini, or Apes of the Old World.

Of these the cutting or incisive teeth are $\frac{4}{4}$, the canine $\frac{1-1}{1-1}$, the cheek teeth or grinders $\frac{5-5}{5-5}$; total 32. The nostrils, as the name implies, are separated only by a narrow membrane. The tail, frequently wanting, is never prehensile.

Genus Troglodytes, Geoffroy. *Pithecus*, Cuv. Canine teeth very slightly elongated, and placed close to the incisors and molars, as in man; head rounded; muzzle short; facial angle, 50°;[1] superciliary ridges strongly marked; no cheek pouches, tail, or callosities; no apparent intermaxillary bone; ears resembling those of man, but large and projecting; arms of moderate length.

The only known species of this genus is the Chimpanzee, or black orang of Africa (*Simia troglodytes*, Linn.), the *Troglodytes niger* of the modern system.[2] (See Plate I. of this vol., figure 2.) The colour of the fur is brownish black. The form of the body and limbs more nearly approaches the human than that of any other animal. The head is middle-sized, somewhat flattened in the crown, and scarcely rising above the level of the superciliary ridges. The chest is broad, the arms robust, and the anterior thumb is placed lower on the wrist, and seems more serviceable than that of the Asiatic species.

Although we feel desirous to render the present treatise not only useful to the scientific student, but in some measure interesting to the general reader, by the occasional introduction of what is called *popular* matter, we would rather at present hold ourselves excused from the repetition of the various anecdotes which might be brought forward without much effort, to illustrate the history of this and the other orang.[3] Many of these are apocryphal, and, though amusing, tend to mislead rather than instruct. Two species of African orang-outang seem to have been described by ancient writers, but as from all later researches we cannot infer the existence of more than the one above indicated, it is probable that the mistake originated from the young and old of the same species having been seen apart at different times. "The greatest of these two monsters," says Battell, "is called *Pongo*, and the less *Engeco*. This Pongo is exactly proportioned like a man; but he is more like a giant in stature, for he is very tall, and hath a man's face, hollow-eyed, with long hair upon his brows. His face and ears are without hair, and his hands also. His body is full of hair, but not very thick, and it is of a dunnish colour. He differeth not from a man but in his legs, for they have no calf. He goeth alway upon his legs, and carrieth his hands clasped on the nape of his neck when he goeth upon the ground. They sleep in the trees, and build shelters from the rain. They feed upon fruits that they find in the woods, and upon nuts; for they eat no kind of flesh. They cannot speak, and appear to have no more understanding than a beast. The people in the country, when they travel in the woods, make fires where they sleep in the night; and in the morning, when they are gone, the pongos will come and sit about the fire till it goeth out; for they have no understanding to lay the wood together, or any means to light it. They go many together, and often kill the negroes that travel in the woods. Many times they fall upon the elephants which come to feed where they be, and so beat them with their clubbed fists, and with pieces of wood, that they will run roaring away from them. Those pongos are seldom or never taken alive, because they are so strong that ten men cannot hold one of them; but yet they take many of their young ones with poisoned arrows. The young pongo hangeth on his mother's belly, with his hands fast clasped about her, so that when the country people kill any of the females, they take the one which hangeth fast upon its mother, and, being thus domesticated and trained up from their infant state, become extremely familiar and tame, and are found useful in many employments about the house."

Purchas states, on the authority of a personal conversation with Battell, that an African orang once carried off a young negro, who lived during an entire season in the society of these animals, and on his return reported that they had never injured him, but, on the contrary, seemed greatly delighted with his company; and that the females especially (this was natural) shewed a great predilection for him, and not only brought him great abundance of nuts and wild fruits, but carefully and courageously defended him from the attacks of serpents and beasts of prey. According to Pyrard, the great Ape of Sierra Leone called *Barris* (undoubtedly the adult black orang) is so remarkable both for strength and industry, that when properly fed and instructed, it serves as a very useful domestic. It usually walks upright (so it is alleged, we doubt not most erroneously), will pound any thing in a mortar, or fetch water from the river in a little pitcher, which, however, must be immediately taken from it on its return, else it will allow it to tumble to the ground. Passing by the impostures of Gamelli Careri, it may be asserted that the equally amusing, and scarcely more authentic, narrations which Buffon and others have compiled from the writings of Father Jarrie, Guat, and Froger must be consulted with critical caution by whoever seeks to ascertain the actual history of this extraordinary creature. With the exception of such information as has been drawn from the observance of one or two young individuals sent alive to Europe, our knowledge of its nature has in no way increased. Naturalists have become aware of the inaccuracy and exaggeration of previous portraitures, but have not themselves succeeded in the completion of the picture. It is indeed most singular that when the history of animals inhabiting New Holland, or the most distant islands of the Indian Ocean, are annually receiving some new or corrected illustration, the most remarkable species of the brute creation, inhabiting a comparatively neighbouring country, should have remained for about two thousand years under the uncertain shadow of an almost fabulous name. The African orang appears to be a gregarious animal, an inhabitant of the forests, of an intelligent disposition, and capable of a considerable degree of education, though probably fierce and irreclaimable in the adult state. It is believed that the full grown animal has never yet been examined by any naturalist. In that uncouth condition it is probably the "great wild man of the woods," of whose existence we do not doubt, but of which (setting aside the obviously fabulous narrations) only vague indications have been given by some African travellers.

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[1] In accordance with the usual custom of naturalists, we here occasionally indicate the facial angle, although we are satisfied that that character admits of too wide a range of variation to be relied upon as a *specific* indication. An examination of an extensive series of skulls in the Museum of the College of Surgeons (Edinburgh), had long ago convinced us that remarkable changes take place in the form and proportions of the cranium in the same species, according to the age of different individuals. For example, in the dog, badger, common pig, and especially in the *Sus Babyroussa*, these differences are very remarkable.

[2] *Homo sylvestris*, Tyson; *Man of the Woods*, Edwards; *Great Ape*, Pennant; *Jocko*, Buffon; *Pongo* of Audebert, and of the Supplement to Buff. tom. 7; but quite distinct from the Pongo of Wurmb. This animal was dissected by Professor Traill, who discovered in it a motor muscle of the thigh that had escaped the notice of Tyson, Camper, and Cuvier. (*Wern. Trans.* vol. iii.)

[3] We beg to refer the curious to a very accessible little work, "The Natural History of Monkeys," which forms a volume of Sir William Jardine's interesting and economical *Naturalist's Library*. A book entitled *Anecdotes of Monkeys* was previously before the public.

Of the natural dimensions of the black orang, we can say nothing. The young brought to Europe have seldom much exceeded two feet in height. It is native to no other country than Africa, but we are as yet unacquainted with the extent of territory which it occupies in that continent. Angola, the banks of the river Congo, and all the districts which border the gulf of Guinea, are the localities in which it has as yet most frequently occurred.

GENUS PITHECUS, Cuv. Geoff. Canine teeth somewhat exceeding the others in length, but not separated from them by any interspace, and slightly crossing each other at their points; molar teeth more square than those of man, and more strongly tuberculated; head rounded; facial angle 65 degrees; no superciliary ridges;[1] no cheek pouches, tail, or callosities; sutures of the intermaxillary bone apparent; ears rounded, resembling those of man, and applied close to the sides of the head; arms very long.

This genus likewise consists of only one clearly ascertained species, commonly called the red or Asiatic orang-outang (*Simia satyrus*, Linn.), the *Pithecus satyrus* of the modern systems.[2] (See Plate I., figure 1.) Like the preceding it is not distinctly known in the adult state. The specimen described by Dr Clarke Abel,[3] was brought from Banjarmassing on the south coast of Borneo. Its height, or rather length, from the heel to the crown of the head was two feet seven inches. The hair was of a brownish red colour, and covered the back, arms, legs, and outside of the hands and feet. On the back it was in some places six inches long, and five upon the arms, but very short and thinly scattered on the back of the hands and feet. It was directed downwards on the back, upper arms and legs, but upwards on the fore-arms. The face had no hair except on the sides, somewhat in the manner of whiskers, and a very thin beard. The palms of the hands and feet were quite naked. The arms were long in proportion to the height of the animal, their span measuring full four feet seven inches and a half. The legs were short compared with the arms. The hands were long compared with their width, and with the human hand. The fingers were small and tapering, the thumb very short, scarcely reaching to the first joint of the fore-finger. All the fingers had perfect nails of a blackish colour, and oval form, and terminating exactly with the extremities of the fingers. The feet were long, and as usual resembled hands in the palms and finger-formed toes, but they were likewise provided with good heels. The great toes were very short, attached at right angles to the feet close to the heel, and were entirely without nails.

This animal was utterly incapable of walking in a perfectly erect position, and never wilfully attempted so to do. His progressive motion on a flat surface was accomplished by placing his bent fists upon the ground, and drawing his body between his arms, moving in the manner of a decrepit person supported on stilts. It is thus probable that in a state of nature he scarcely travels on the ground at all, his whole external form and structure proving his fitness for climbing trees and clinging to their branches. While in Java, he lodged in a large tamarind tree near Dr Abel's dwelling, and formed a bed by intertwining the smaller branches and covering them with leaves. He exhibited few of the grimaces of the monkey tribe, and was in no way prone to mischief. His aspect was grave, mild, almost melancholy. His chief amusement consisted in swinging himself from bough to bough; and, when on board of ship, he made use of the various tackling for the same purpose. On only two occasions was he seen violently agitated. When the vessel in which he sailed was off the island of Ascension, eight large turtle were brought on board, when he instantly mounted to a higher part of the ship than he had ever reached before, and, looking down upon the reptiles, projected his long lips into the form of a hog's snout, uttering at the same time a most peculiar cry. He enacted the same part on another occasion, on seeing some men in a state of nature splashing in the sea. Perhaps he took them for Mr Swainson's desired natatorial type of the quadrumanous order. We regret to add, that he died in the course of his second year's residence in this country. Our climate, in spite of coal fires and pipes of steam, is too cold, moist, and variable for these dwellers in the tropic woods, and a complaint analogous to consumption speedily puts a period to their shivering existence.

It is the opinion of Baron Cuvier,[4] that an obscurely known and almost gigantic animal, described by Wurmb[5] under the name of the Pongo of Borneo, ought to be regarded as the adult condition of the Asiatic orang-outang. The reasons assigned for this alleged identity, so far as we can collect them, from a notice on the subject by M. de Blainville,[6] are chiefly these:—As no orang-outang has ever been seen in Europe, or described by any European naturalist which exceeded the age of two or at most three years, it has consequently never been observed at all in the adult state. Observation has demonstrated, that the muzzles of apes in the menagerie of the Jardin du Roi prolong considerably with age; and it is known that the facial angle, both in men and monkeys, decreases as the individuals advance in years. The compression of the cranium has also been observed to take place from natural causes in after life. In the year 1818, Baron Cuvier received from India the head of an orang-outang, which resembled the ordinary species (the red orang) in most respects, but was remarkable for the prolongation of the muzzle, and the development of the superciliary ridges. Its characters were, in short, intermediate between those of the Asiatic orang-outang and the pongo of Borneo, from which it is concluded, that the former, in the state in which we have hitherto known it, is the young of the latter, the specimen adduced by Cuvier being regarded as an adult example of the same species, which had not, however, attained the maximum of its development. That the skeleton of the pongo in the Paris Museum was of great age, is proved by the general condition of its ossification, the state of its teeth, and the great development of the osseous crests of the cranium; the same characters being observed in old baboons, the young of which, without exhibiting so marked a disparity as that which exists between the red orang-outang and the pongo, nevertheless differ greatly from their parents. Lastly, the relative dimensions of the red orang-outang, of the intermediate specimen described by Cuvier, and of the adult pongo, are graduated in exact proportion to the development of the characters drawn from the crests of the cranium, and the prolongation of the facial bones.

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[1] This character, we doubt not, applies only to the young animal. The ridges will probably be found strongly developed in the adult.

[2] *Homo sylvestris*, Edwards; *Jocko* of Audebert and of Buff. Supplem. t. 7, fig. 1.

[3] *Narrative of a Journey into the Interior of China*, p. 319.

[4] *Règne Animal*, t. 1.

[5] *Mem. de la Soc. de Batav.*, t. 2, p. 245.

[6] *Note Sur l'Orang-outang, Jour. de Phys.* t. 1, p. 311.

The preceding observations, if not conclusive, are at least logical. But we cannot help bearing in mind that Sir Stamford Raffles,[1] in mentioning the occurrence of the orang-outang in Sumatra, states that it is there called by the natives orang *Pandak*, or the pigmy. Now, vernacular names are generally bestowed with some perception of natural character and attributes, and it is by no means usual for a people, however unobservant, to bestow, as the general appellation of a species, a title which applies to it only in a state of youthful imbecility; and if the creature in question attained in its adult state to the enormous stature of the pongo or great orang, we conceive it could scarcely do so without being occasionally observed of such a size as to render the name of pandak inapplicable. Nor do we see for what reason the great pongo, an animal of the most wary disposition, and of such extreme rarity, that not more than two or three examples of its occurrence are yet known to naturalists, should bring up its offspring so frequently within the range of human visitation. That it should be itself all the while unknown and invisible within the circle of its own domestic haunts (admitting it to be the parent of the red orang), is a circumstance still more difficult of explanation.

Whether these species, then, are identical or otherwise, is certainly still an undecided point. Another of equal interest and importance regards the specific nature of that gigantic animal killed some years ago on the north coast of Sumatra by Captain Cornfoot or his crew, and likewise described by Dr Clarke Abel.[2] It was upwards of seven feet in height when placed in a standing posture, and measured eight feet when suspended by the neck for the purpose of being skinned. On the spot where he was killed there were several tall trees, which greatly prolonged the attack; for such was his strength and agility, that his pursuers were unable to take a determinate aim, until they had felled all the trees but one. He received numerous balls before he was brought down, and then he lay upon the ground, as dead, exhausted by many wounds, with his head resting on his folded arm. It was at this time that an officer attempted to give him the coup de grace, by thrusting a spear through his body, but he instantly sprang upon his feet, wrested the weapon from his antagonist, and shivered it in pieces. This was his last effort, yet he lived some time afterwards, and drank, it is said, great quantities of water. He appeared to have travelled from some distance to the place of this "untoward event," for his legs were caked with mud up to the knees. On the reception of each deadly wound, he placed his hand over the injured portion, and distressed even his relentless pursuers by the human-like agony of his countenance. Indeed, his piteous actions, and great tenacity of life, are said to have rendered the scene altogether highly affecting. At the same time, it seems odd that so much sentimental perception should have been vouchsafed to those who committed the onslaught, and who were under no absolute necessity of bringing the business to so tragical a close.[3]

Genus Hylobates, Illiger. Muzzle short. Canine teeth lengthened. Facial angle 60 degrees. No tail nor cheek pouches. The posteriors furnished with callosities. Arms extremely long.

This genus contains the species commonly called Gibbons or long-armed apes, none of which are as yet known to attain the formidable dimensions of the great orangs. In their habits they are gregarious, and extremely shy in a state of nature, although their haunts are often betrayed by their singular howlings. In aid of these peculiar cries some of the species possess guttural sacks, resembling those of the howling monkeys of South America. Their distribution is confined to India and the Asiatic islands, where, like all their congeners, they inhabit forests, from which they seldom stray, and out of which they are easily captured, from the extreme awkwardness and difficulty with which they advance on *terra firma*, owing to the disproportionate length of their fore-arms.

Of the species, which are numerous, the most ancient, if not the best known, is the common gibbon, *Hylobates Lar* (*Simia Lar*, Linn.). The fur is entirely black, the face surrounded by grey hairs, the nose flat, and the ears not unlike the human. The disposition of this animal is mild and gentle. In a state of domestication, it receives its food without manifesting any greedy impatience, and exhibits a strong attachment to those with whom it has become acquainted. It is a native of the coast of Coromandel, and occurs also in the Peninsula of Malacca and the Molucca islands. It was probably one of this species which Father le Compte had an opportunity of examining, and which he says walked on two feet, and had "a face like a Hottentot." The white-handed gibbon from Sumatra, formerly regarded as a variety of the preceding, is now described as distinct, under the specific name of *albimana*.[4] We have, moreover, the little gibbon, *H. variegatus*, from Malacca, the active gibbon, *H. agilis*, from Sumatra, Harlan's gibbon, *H. Hoolock*, from the Garrow Hills, the Moloch gibbon, *H. leuciscus*,[5] from Malacca and the isles of Sunda, and the Siamang, *H. syndactyla*, from Sumatra. The last named, which we owe to the valuable researches of Sir T. S. Raffles, is distinguished by this peculiarity (from which it derives its specific name), that the first and second fingers of the hinder hands are united together as far as the middle of the second phalanx. It is entirely black, the face without hair, and the canine teeth long. It usually occurs in large troops, conducted, it is said, by a chief, whom the Malays believe to be invulnerable. Let them try a rifle. These assemblages remain quiet during the day, but at sunrise and in the evening twilight, they cause the forests to resound with the most dreadful cries, sufficient to deprive an unaccustomed traveller of his senses.

Genus Cercopithecus, Erxleben. Cuv. Desm. Canine teeth projecting, with interdentary spaces for their reception when the jaws are closed. Posterior molars with only four tubercles. Head rounded. Muzzle moderately projecting. Facial angle various. Ears of medium size, sometimes rounded, sometimes slightly angular above and posteriorly. Hinder limbs greatly developed. Cheek pouches and callosities. A long tail, not prehensile.

This great generic group is composed of animals named *Guenons* by the French naturalists, and is by far the most numerous and varied of the monkey tribes. It is almost exclusively African in the localities of the species. These live in troops, and commit great devastation in gardens and cultivated fields. They are easily tamed. The genus has been greatly subdivided in recent times, but we cannot here enter into any detailed exposition of the minor groups. We shall briefly describe and characterise a few of the principal species.

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[1] *Linn. Trans.*, vol. xiii, p. 241.

[2] *Asiatic Researches*, vol. xv.

[3] We have figured the hands and feet of this extraordinary orang, of the size of life (from beautiful models transmitted to the Royal Society of Edinburgh from Calcutta, by George Swinton, Esq.). See Wilson's *Illustrations of Zoology*, vol. i. plates 33, and 34.

[4] *Zoological Jour.*, No. xiii. p. 107.

[5] This is the Wou-wou of Camper, but not the species so named by Fred. Cuvier, which is the true *H. agilis*. Wou-wou seems to be a native name of some extent of application, and therefore not specifically distinctive.

The golden guenon (*Cerc. auratus*, Geoff. Ann. Mus., t. 19, 93) has the fur of a golden-yellow colour, and of considerable length upon the ears, cheeks, and forehead. There is a black spot upon the knee. Native of the Moluccas.

The Talapoin monkey of Shaw and Pennant (*Cerc. talapoin*, Geoff. ibid.), is a doubtful species, by some regarded as the young of the Malbrouk. Its locality is uncertain.

The varied monkey of English authors (*Cerc. mona*, Geof. ibid. p. 95) is distinguished by its flesh-coloured lips and nose. The upper part of the head is a brilliant golden-green; the back and sides of a lively chesnut colour, speckled with black; the upper parts of the legs, thighs, and tail are of deep slaty grey, passing into black; and there are two white spots on each buttock. This is an African species, regarded by Buffon as the *Kebos* of the ancients. It is remarkable for its graceful motion, its elegance of form, and gentle docility of disposition.

The red monkey (*Cerc. ruber*, Geoff. ibid. p. 96), has the face flesh-coloured, the ears black; a black band passing over the eyebrows, and two black lines above the lips, give the appearance of moustachios. The upper parts of the face are of a bright reddish fawn colour, passing beneath into ash colour. From Senegal.

The Palatine monkey (*Cerc. Diana*, Geoff. ibid.), is of a deep chesnut colour on the back, with grey flanks, a pale oblique line upon the thighs, the chin and throat white, and a white crescent on the forehead,—from whence the mythological specific name. Congo and the coast of Guinea.

GENUS CERCOCEBUS, Geoff. Teeth as in preceding genus. Muzzle rather long. Head triangular. Facial angle about 45 degrees. Superior margin of the orbits paired, and notched interiorly. Nose flat and high. Anterior hands with slender thumbs, approximate to the fingers; posterior hands with broader thumbs, placed more apart. Callosities strongly developed. Tail longer than the body.

Here we place the Callithrix or green monkey (*Cerc. sabæus*), a well-known species from the African coasts and the Cape de Verd Islands, frequently imported alive into this country. Its colour is greenish-yellow above, somewhat grizzled on the sides of the body and outsides of the limbs, which become gradually darker towards the hands. The face, ears, and hairless portions of the hands are quite black. The neck and chest are white; the under parts have a tinge of yellow, and the insides of the limbs are grey. An account of the shooting of this species is given by M. Adanson. "But what struck me most, was the shooting of monkeys, which I enjoyed within six leagues this side of Podor, on the lands to the south of Donai, otherwise called Coq; and I do not think there ever was better sport. The vessel being obliged to stay there one morning, I went on shore, to divert myself with my gun. The place was very woody, and full of green monkeys, which I did not perceive but by their breaking the boughs on the tops of the trees, from whence they tumbled down upon me; for in other respects they were so silent and nimble in their tricks, that it would have been difficult to hear them. Here I stopped, and killed two or three of them, before the others seemed to be much frightened; however, when they found themselves wounded, they began to look for shelter, some by hiding themselves among the large boughs, others by coming down upon the ground; others, in fine, and these were the greatest number, by jumping from one tree to another. Nothing could be more entertaining, when several of them jumped together on the same bough, than to see it bend under them, and the hithermost to drop down to the ground, while the rest got further on, and others were still suspended in the air. As this game was going on, I continued still to shoot at them; and though I killed no less than three-and-twenty in less than an hour, and within the space of twenty fathoms, yet not one of them screeched the whole time, notwithstanding that they united in companies, knit their brows, gnashed their teeth, and seemed as if they intended to attack me."[1]

Another well-known species is the Malbrouc of Buffon, the dog-tailed baboon of Shaw (*Cerc. cynosurus*, Geoff.). It is of an olive-brown above, whitish beneath, with a pale band above the eyes. This species is one of the largest of the guenon group, measuring about a foot and a half from muzzle to tail. It possesses remarkable dexterity in the use of its hands, and although when aloft it is one of the most agile of all the wood-haunting animals, its motions on the ground are extremely awkward from the disproportionate length of the hinder limbs. We find, accordingly, that the malbroucs rarely descend to the earth. "Assembled in troops, they dwell for the most part in those capacious canopies of verdant foliage which cover the rich forests of Southern Asia, fellow-citizens with the birds, exposed to no danger but from the larger of the serpent tribe, or the more insatiable rapacity of man. In these lofty retreats they are found in such numbers, as to annoy the traveller, as well by the petulance of their motions, as the incessant iteration of their cries."[2] The Malbrouc in confinement is an unsociable creature, being either petulant and irritable, or morose and melancholy. He is mischievous when indulged, and sulky when kept in order. He inhabits Bengal. Numerous other species pertain to the generic group named *Cercocebus*.

GENUS SEMNOPITHECUS, F. Cuv. Canine teeth much longer than the incisors. The posterior molars of the lower jaw with a fifth tubercle. Tail and members long in proportion to the size of the body. Anterior thumb very short. Muzzle not greatly projecting. Cheek pouches and callosities.

The negro monkey of Pennant (*Sem. Maurus*, Geoff.) is entirely of a black colour, with the exception of a white spot beneath, at the base of the tail. It is said to be of a fawn colour when growing, and inhabits the island of Java. The only other species we shall mention of our present subdivision, is the Entellus Monkey of M. Dufresne (*Sem. Entellus*, Cuv.), which is of a pale yellowish-grey colour, with black hair on the eyebrows and sides of the head, directed forwards. Although systematically described only during recent years, it has long been well known in Bengal, and is one of the species venerated in the religion of the Brahmins. Its motions are slower than those of most monkeys, and the expression of its countenance betokens unalterable apathy. The height of the specimen in the London Zoological gardens exceeded two feet when in a sitting posture. The tail, which was rarely unfurled, measured nearly three feet. According to Mr Bennet, it is identical with the Ceylonese species described by Thunberg and Wolf. It is said to be frequently found in a domestic state in Ceylon, and is held in such respect by the natives, that whatever ravages it may commit, the latter dare not venture to destroy it, but merely frighten it away by cries, if possible, more discordant than its own. "Emboldened by this impunity, these monkeys come down from the woods in large herds, and take possession of the produce of the husbandman's toil with as little ceremony as though it had been collected for their use."[3]

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[1] *Voyage to Senegal.*

[2] Griffith's *Animal Kingdom*, vol. i. p. 267.

[3] *The Gardens and Menageries of the Zoological Society delineated*, vol. i. p. 86.

Genus Macacus. Lacep. Posterior molars furnished, as in the preceding, with a fifth tubercle, but the limbs are proportionally stouter and shorter. The tail is likewise shorter, and the superciliary ridges are distinct.

The only example we shall here name is the Wanderou (*M. Silenus*), a large black species, of which the sides of the head and chin are surrounded by a broad beard or ruff, of a dingy white, or pale-grey colour. The tail is terminated by a tuft of hair, on which account it appears to have been named by some the lion-tailed monkey. "The princes and great lords," says Father Vincent Marie, "hold him in much estimation, because he is endowed above every other with gravity, capacity, and the appearance of wisdom. He is easily trained to the performance of a variety of ceremonies, grimaces, and affected courtesies, all which he accomplishes in so serious a manner, and to such perfection, that it is a most wonderful thing to see them acted with so much exactness by an irrational animal." We were never acquainted with more than one living individual of this species, and the only piece of "affected courtesy" it ever exhibited, consisted in nearly biting off the calf of a negro's leg. The Wanderou is a native of Ceylon.

Genus Innuus, Cuv. Characters similar to those of the preceding genus, except that the tail is so short as to seem tubercular.

The well-known Magot or Barbary Ape (*Innuus sylvanus*, Cuv., *Simia innuus*, Linn.), remarkable as the only species of the quadrumanous Order found in Europe, may be adduced as a characteristic example of the present genus. (See Plate I., figure 4.) This species inhabits the rock of Gibraltar, and the nearly opposing point of Africa called Apes Mountain. It does not, however, occur in desert countries, commonly so called; the open sandy plains of Africa being altogether unadapted to the dwellings of this pigmy people. Indeed apes of all kinds are a sylvan race. Their structure being such as to render them unfit for the exercise of rapid movement, either on all-fours, or in an upright position, the intwined and densely intermingled branches of trees are their favourite places of resort. Their feet in climbing being equally useful as their hands, great additional power and activity are thus derived. Among the shady and otherwise unpeopled arbours which skirt the banks of the yet mysterious rivers of Africa, they dwell in single pairs, or in congregated groups, according to the instinct of each particular kind; and seated on the tops of ancient trees, or swinging from pendant boughs, they play their fantastic tricks, secure alike from the wily serpent during the day, and the panther which prowls by night.[1] The species in question, which also inhabits Egypt, is supposed to be the *Pithecus* of ancient writers.

Genus Cynocephalus, Cuv. Canine teeth very strong. Superciliary and occipital ridges very distinct. Head and muzzle lengthened, the latter truncated at the point; nostrils terminal. Face furrowed by longitudinal striæ. Cheek pouches and callosities.

The species which compose this genus, notwithstanding their resemblance in some respects to the human face and figure, are among the most disgusting and degraded of the brute creation. Their colouring is occasionally brilliant, and their fur long and ornamental; yet there is an expression of moral deformity in their aspect, at which we cannot help revolting. Their habits in a state of nature are said to be extremely ferocious, and in confinement their propensities seem all of the most odious kind. Their strength, in comparison with their apparent size, is enormous. By muscular energy alone, and without the assistance of their huge tusks, they will in a few minutes tear the strongest dog to pieces. Fortunately with all their fierceness, they are not carnivorous, otherwise the most dreadful of the feline races would prove less formidable foes. In the wild state they subsist principally on roots and fruits, although eggs and young birds are believed to form a portion of their occasional sustenance. The species are almost exclusively African, and are subdivided into the two following groups.

a. *Tail Long.* Baboons.

The Guinea baboon (*Cyn. Papio*, Desm.), has the fur of a yellowish-brown colour; the face entirely black. The cartilage of the nose exceeds the jaws at its upper extremity. The upper eyelids are white. It occurs on the coast of Guinea.

The pig-faced baboon (*Cyn. porcarius*, Desm.), has the fur of a greenish-black above; the face of a violet black, paler around the eyes; the upper eyelids white. The tail is long and tufted, and, in the adult state, there is a kind of mane upon the neck. It inhabits the Cape of Good Hope. (See Plate I., figures 3 and 3 *a*.)

b. *Tail Short.* Mandrills.

The variegated or ribbed-nosed baboon of English writers (*Cyn. mormon*, Desm., *Simia maimon* and *mormon*, Linn.), is of a greyish olive-brown above, beneath white, with a yellow beard, and blue face; and (in the adult male) a red nose. It is scarcely possible to conceive a more extraordinary looking animal. It possesses great strength, and is said to be much dreaded by the negroes. The well-known "Happy Jerry" of Exeter Change belonged to this species. He was too much addicted to gin and water. We have figured as an illustration of this division, the species commonly called the Drill, *C. leucophæus*, Desm. It is of African origin. (See Plate I., figure 5.)

We here terminate our sketch of the first sub-family, or Simiæ Catarrhini, composed of all the animals of the Ape kind peculiar to the ancient world, and shall now proceed to the

2d Sub-Family.—Simiæ platyrrhini, or Apes of the New Continent.

Six molar teeth on both sides of each jaw, bluntly tubercular, or only five, with acute tubercles.[2] Nostrils opening on the sides of the nose, and separated by a broad partition. Tail always long, and frequently prehensile, that is, endowed with the power of grasping. No cheek pouches, nor posterior callosities. Head usually of a roundish form.

1st Division. *Tail long and prehensile.* The Sapajous.

Genus Ateles, Geoff. Molar teeth 24 in all, with blunt crowns. Facial angle about 60 degrees. Head round; members slender; thumb wanting, or nearly so, on the anterior hands. Tail extremely long and very prehensile, with a bare space beneath at the extremity.

The species of this genus seem to be of a mild, timid, melancholy character, and more indolent in their movements than most of the monkey tribe. A beholder is apt to believe them sick, or in a state of sufferance. It is known, however that, when necessary for their own safety they can exhibit great alacrity. They dwell in troops amid the lofty branches of forest trees, and feed chiefly on fruits; but they are alleged to eat also insects and small fishes, and to have been seen picking up oysters and other testaceous mollusca when the tide was low, and bruizing them between two stones. So at least says Dampier. D'Acosta adds as another trait of their great natural intelligence, that when they wish to pass from one tree to another without descending, they form a lengthened chain by hanging to each other's tails, and swing with a pendulous motion, till one of them catches hold of an opposing branch. The genus is spread over a great extent of South America, and contains a considerable amount of species, some of which (forming the genus *Eriodes* of Is. St Hilaire), in the thin partition of the nostrils, and their downward instead of lateral opening, seem intermediate between the monkeys of the old world, and those of the new.

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[1] *Edinburgh Cabinet Library*, vol ii. p. 444, 2d edition.

[2] None of the American monkeys have fewer than 24 molars, except the Ouistitis (*Hapale*, Illiger), in which the amount is the same as in the species of the Old World, i. e. 20.

a. *A very small, or rudimentary anterior thumb.*

The Miriki monkey (*Ateles hypoxanthus*, Kuhl) is a species discovered in Brazil by Prince Maximilian of Neuwied. The fur is of a yellowish-grey colour, the face flesh colour, with grey spots. In some specimens the anal region and origin of the tail are rusty red. The miriki greatly resembles the spider monkey (*A. arachnoides*, Geoff.), but the latter wants the rudimentary thumb. The only other species of this subdivision is the *Ateles subpentadactylus* of Desm., the *Chamek* of Buffon.[1] It has no nail upon the rudimentary thumb.

b. *No rudimentary anterior thumb.*

The Marimonda monkey of Humboldt (*Ateles Beelzebub*, Geoff.) is one of the most noted species of this subdivision. The fur is brownish-black above, of a dingy or yellowish-white on the abdomen. It is one of the most common species in Spanish Guiana, and occurs in immense numbers along the wooded banks of the Oronooko, where they are seen hanging as it were in festoons, suspended from the branches, and holding by each other's hands or tails. They are also sometimes observed for hours at a time, sitting with heads upraised, and folded arms, exposing themselves to the scorching rays of the noon-day sun. The prehensile power of the tail is remarkable in this species, and probably makes amends (in accordance with that providential arrangement which the French naturalists designate as *la loi du balancement des organes*) for the somewhat defective structure of the anterior hands. The marimonda is frequently used as food in South America, and would be speedily relished even by strangers, but for the child-like aspect of the heads, which, when turning round in a tureen of soup, give rise to most extraordinary and unpleasant associations. There are about ten species of *Ateles* described by naturalists, including those which constitute the genus *Eriodes* of M. Isid. St Hilaire.

Genus Lagothrix, Geoff., Humb. Amount of molar teeth as in Ateles. Facial angle about 50 degrees. Muzzle projecting, head round. Thumbs on all the extremities. Hair soft and frizzly.

Of this genus there are not more than three species known, and one of these is doubtful. Little has been ascertained of their natural economy. They are gentle in their dispositions, of gregarious habits, and are usually seen sitting on their hind legs.

Genus Mycetes, Illiger. Teeth the same in number as in the preceding genera, but the canines are more developed. Facial angle scarcely more than 30 degrees. Head pyramidal, visage oblique. Hyoid bone much enlarged, cavernous, and producing externally an inflation of the throat. Nails short and convex.

The species of this genus known under the name of Alouattes, or howling monkeys, are the largest and fiercest of the quadrumanous tribes of South America. Their powers of voice are extraordinary, and result, we doubt not (though no detailed demonstration of the fact has yet been afforded) from the peculiar construction of the hyoid bone, and the parietes of the larynx.[2] "Though the animals of the American continent differ in many material points from those of the old world, yet is there almost always a general analogy between them, an analogy sometimes also observable even between the minor subdivisions. We might be justified, for example, in calling the Alouattes, or howling monkeys, the baboons of the new world. They approximate to them in size and fierceness, and are perhaps still less susceptible of culture, and still less amenable to the discipline of man. They are in truth distinguished for wildness and ferocity, and the bony structure in their throats, which gives to the voice such tremendous force and volume, adds in no small degree to the terror which they are otherwise calculated to inspire. They wander in large troops, chiefly in the night, and make the vast forests resound with their dreadful yellings. What heightens the effect is, that they howl in concert; the entire herd joining in one deafening cry the instant they discover the approach of an intruder."[3]

Some of the species of our present genus are so numerous, that Humboldt has counted forty on a single tree, and his calculation is, that in certain districts more than 2000 exist in one square league. We receive various and somewhat contradictory statements of their history and habits from different travellers. All agree that a practised marksman is required, whether with bow and arrow or *les armes à feu*, to bring them to the ground, because, unless shot at once through the brain, their prehensile tail immediately entwines itself around a branch, and keeps its owner suspended even after death, unless that event is almost instantaneous. The females appear to produce only a single young one at a time. According to Azzara, the mother when alarmed is apt to abandon her offspring, and various other voyagers report that the instinct of maternal love is less pervading in our present tribe than among the majority of monkeys. The traveller Spix, however, relates that he mortally wounded a female, who continued to carry her offspring on her back, till she was about to expire from loss of blood, when, by a last effort, she threw her precious burthen among the neighbouring branches, and fell exhausted to the ground. Oexmelin, the author of "l'Histoire des Aventuriers," also alleges that the female howlers are remarkable for their attachment to their young; that they succour and assist each other under various difficulties; and that when one is wounded, the rest assemble around him full of compassionate sympathy, and even attempt to stop the flowing of the life-blood from the perforation of the deadly bullet. "I have witnessed this," says the author, "many times with admiration." It is certainly one of the advantages of travelling into "far countries," that one is thereby enabled to see many wonderful sights, of a nature seldom seen at home. Spix states that the howlers are monogamous. Azzara is of a contrary opinion. It is admitted that they spring with great agility from branch to branch, confiding in the powers of their prehensile tail, should their quadrumanal efforts prove fallacious. They live on fruits and insects, and seem to delight more than others of their kind in the vicinity of streams and marshes. Hence they roam either along the banks of rivers, or among those wooded islands of the moist savannahs, which are subject to frequent inundations. They even inhabit, according to Legentil, the marine Ile Saint George, two leagues from the main land. The howlers are rarely reared in captivity, their dispositions being unamiable, their voices unendurable, and their natural instinct little susceptible of amelioration by the human race. It is probably for these reasons that we scarcely ever find them brought alive to Europe, notwithstanding our constant commercial intercourse with the countries which they inhabit. Naturalists do not seem to be well acquainted with more than seven species of howlers. For their detailed descriptions we must refer the reader to the writings of Marcgraaff, Azzara, Geoffroy, Humboldt, Kuhl, Desmarest, and Spix.[1]

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[1] A curious anomaly has been observed in a specimen of *Chamek*, viz. the existence of seven grinders on the right side of each jaw.

[2] See Humboldt in *Observations Zoologiques*, and the *Diction. Class. d'Hist. Nat.* t. xv. p. 131.

[3] Griffith's *Animal Kingdom*, vol. 1. p. 301.

Genus Cebus, Erxleben. Teeth the same in number as in the preceding genera, but the upper incisors are broader than the under. The head is round, the muzzle short, the forehead slightly prominent, the occiput projecting backwards. Facial angle about 60 degrees. Ears rounded. Hyoid bone not inflated. Anterior thumb elongated. Tail prehensile, but furred throughout its entire extent.

In this genus, which includes the Sapajous properly so called, the members are strong and lengthened, especially the hinder extremities. They consequently leap about with great activity. Like their congeners they are gregarious, and live in trees. Their disposition is lively, but less petulant than that of the guenons of the Old World. Their cranial development is large, and their intelligence proportional. They are easily tamed, and very tractable. Our knowledge of their natural history is very slight, most of the facts by which we could illustrate their habits having been drawn from the observance of their captive state. The younger St Hilaire informs us that they indulge in abstract ideas, his proof being that he once observed a Sapajou, which had met with a nut somewhat harder than usual, descend from the top of a wooden cage, and crack the said nut by bruising it against an iron bar. "Cette observation," he remarks, "nous paraît digne d'être citée; car elle prouve d'une manière incontestable que notre sajou abandonné à lui-méme et sans avoir jamais reçu aucune éducation, avait su reconnaître que la dureté du fer l'emporte sur celle du bois, et par consequent, s'etait élevé à un rapport, *à une idée abstraite*." It is delightful to find metaphysics thus combined with natural history. The Sapajous are rather omnivorous in their propensities, for although they feed chiefly on fruits, they are also avidous of insects, worms, and mollusca. The species occur principally in Brazil and Guiana, and are sometimes known under the name of musk-apes, from a peculiar odour which they emit during the rutting season. They have also been denominated *weepers*, from their occasional utterance of a certain plaintive and disconsolate cry.

The sapajous of our present genus, as M. Desmarest has well observed, are extremely difficult to characterize. Their size and general form and aspect exhibit a great similarity, and authors differ considerably as to the amount of species. Brisson describes three, Linnæus four, Gmelin six, Buffon two, and recent authors (Kuhl, Humboldt, Desmarest) above a dozen. We must here, however, content ourselves with the preceding generalities, and a slight indication of one or two species.

The most familiarly known in this country in the living state, is that called the weeper monkey (*Cebus apella*, Desm.) (Plate I., figure 6.) The fur of this species is of a brown colour, deeper above than below. The face is brown, encircled by darker brown hairs. The top of the head, tail, and feet are blackish-brown. This species inhabits Guiana, and is of a hardy, playful, and contented disposition. It sometimes breeds in confinement.

The white fronted sapajou (*Cebus albifrons*, Desm.) has the fur of a grayer colour than that of the preceding. The top of the head is black, the front and orbits white, the extremities of a brownish-yellow. This species, the ouavapavi of Humboldt, is found in troops near the cataracts of the Oronooko. It is a great favourite among the natives, on account of its gentle docility, and the pleasing and elegant alacrity of its movements. A tame one observed by Humboldt at Maypures, seemed to have acquired indolence by domestication. It was in the habit of catching a pig every morning, and continued sitting on its back throughout the day, while it fed in the neighbouring savannahs.

2d Division. *Tail long, but not prehensile.* The Sagouins.

The Sagouins, in general, are distinguished from all the preceding genera of American monkeys, by their tails being destitute of the prehensile or grasping power; and this deficiency, trifling though it seems, brings with it a considerable change of character. Being unable to suspend themselves from the far branches of forest trees, they more frequently seek protection in the denser brush-wood, or among the escarpments of rocky banks. The structure of their eyes seems well adapted for nocturnal vision.

Genus Saguinus, Lacép. *Callithrix*,[2] Geoff. Cuv. Desm. Canine teeth of medium size, lower incisors vertical, and contiguous to the canine. Head small and rounded; muzzle short. Facial angle 60°. Partition of the nostrils not so broad as the range of the superior incisors. Ears very large.

We have acquired as yet a very limited knowledge of the natural habits of this genus. It is ascertained that the species exhibit great intelligence (which might almost be inferred from the large development of the cranium), feed on fruits and insects, and dwell gregariously among the equatorial forests of the New World.

The type of this genus is the beautiful Saimiri of Buffon, the squirrel monkey of our English authors (*Saguinus sciureus*). It is a small and elegant species, of an olive-gray colour, the muzzle black, the legs and arms bright red. It is remarkable for its rounded head, and the flatness of its visage. Its physiognomy is extremely like that of a human infant, but much more pleasing than that of many. It has the same expression of innocence, mingled occasionally with something more malign, and in its expression there is the same frequent and rapid alternation from joy to sorrow. When chagrined, its little eyes are seen to fill with tears. It inhabits Brazil and Cayenne, and is common to the south of the cataracts of the Oronooko, and along the wooded shores of the Rio-Guaviaré. The natives hold it in great request, on account of its beauty, its docile manners, and the general sweetness of its disposition. It is among the most restless of living creatures, but its every movement is full of grace. It is extremely fond of spiders and other insects, and Humboldt observed it exhibit an amusing though mistaken sagacity, in singling out some engravings of these tribes, and endeavouring to pick them off the paper with its paws.[3] It exhibits remarkable adroitness in the capture of living insects, and, under proper culture and control, might possibly be made a very useful *aide-du-camp* to an entomological collector. The young refuse to abandon the dead body of their bleeding mother, and it is only through the strength of this beautiful instinct that they can be captured alive. The affection, according to Geoff. St Hilaire, corresponds with the large development of the posterior lobes of the brain. The individuals appear to vary considerably with age or other circumstances.

A much rarer species of the genus is the widow monkey (*Saguinus lugens*), of which the colour is blackish, the throat and fore-hands white. The fur of this creature is very soft and lustrous, the character melancholic, the habit solitary. It dwells in the forests of the Cassiquiare and the Rio-Guaviaré, and is also found among the granitic mountains of the right bank of the Oronooko, behind the mission of Santa Barbata. Several other species are well known to naturalists.

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[1] See also the article *Sapajous*, in *Diction. Class. d'Hist. Nat.* t. xv. p. 131.

[2] We adopt the generic title of *Saguinus* long since proposed by M. Lacépède, both on account of its prior claim, and its being a less inappropriate name than *Callithrix* (an ancient *Homeric* appellation) for an *American* group.

[3] *Recueil d'Observ. Zool.* p. 322.

Passing over the genus *Nocthores* of F. Cuvier (*Aotus*[1] of Illiger), which contains the curious nocturnal monkey called Dourouculi by the natives of the Oronooko, we come to the more extensive

GENUS PITHECIA, Desm. Incisive teeth approached, the superior oblique and broad, the inferior long and narrow, converging towards their points, and separate from the canines. Canines strong. Partition of the nostrils broad. Head round, muzzle short. Facial angle about 60 degrees. Ears of medium size, margined, and in form resembling those of the human race. Tail clothed with long hair. Nails short and curved.

The species of this genus are known under the various names of Sakis, fox-tailed monkeys, night-monkeys, &c. They are not strictly nocturnal, but move about chiefly during the evening twilight and the early morn. They inhabit the forests of Brazil, Guiana, and Cayenne, and live on fruits and insects. Their habits are but slightly known, probably in consequence of their seldom stirring much abroad throughout the day. They are said to dwell in small groups of seven or eight individuals, and search with avidity for the nests of wild bees. (See Plate II., figure 1.)

Naturalists are acquainted with eight or nine species of Saki. The only one we shall here allude to is the hand-drinking saki (*Pithecia chiropotes*, Humb.), so called from its peculiar mode of imbibition. It lifts the water in the hollow of its hand, and, leaning its head to one side, conveys the liquor to its mouth. It becomes almost furious when its beard is wetted, an aversion which has probably induced it to adopt the peculiar habit just mentioned, but from what principle this aversion springs, we are not prepared to say. The fur of this singular creature is of a chesnut-red colour. It has a long tufted beard, and a thick bush of hair, separated in the middle, and hanging down on each side of the head. In Humboldt's opinion, it more nearly resembles the human race than any other monkey of America. Its eyes, according to that author, have an expression of melancholy mixed with ferocity. It is, moreover, robust, active, untameable, and, when irritated, will raise itself upon its hinder extremities, grind its teeth, stroke down its beard as if it were a Turk, and fly at the offending person with a fury quite unbecoming the semblance of South American humanity. Yet it is habitually melancholy, and, in the captive state, is never excited to gaiety, unless it may be for a few brief and hungry moments at the sight of some favourite food. Why, indeed, should it be gay, pent up in some wretched crib, a collared slave, far from its "friends and brothers," and destined never more to swing from lofty and umbrageous boughs, nor listen from the depths of darkened forests to the roaring cataracts of the Oronooko, where all its "young barbarians are at play?"

GENUS JACCHUS, Geoff. Desm. Incisive teeth $\frac{4}{4}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{5-5}$ (sharply tuberculated); $= 32$. Thumb of the anterior hands not opposable to the fingers. Nails long, compressed, and pointed, except upon the hinder thumbs.

The beautiful and graceful creatures which constitute our present genus (of which the striated monkey of Pennant, *Jacchus vulgaris*, Geoff. (see Plate II., figure 2), may serve as a familiar example), differ in the number of their molar teeth from all the preceding genera of American Quadrumana.[2] Their habits are equally arboreal, although in climbing trees, they are supposed to make use of their pointed nails, somewhat after the manner of squirrels, a tribe of animals to which, in several other respects, they bear resemblance. Their natural history, properly so called, is little known, most of the facts narrated in books being drawn from the observation of individuals in the domestic state, to which they are frequently reduced, on account of their small size and great beauty. M. Audouin of Paris had a pair of ouistitis (for so these creatures are often called) for some time in his possession, and made several curious observations on their faculties and dispositions. They not only recognised themselves and each other in a glass (a perception denied to the sagacious dog), but even detected the nature of various animals as represented in paintings. Thus, the representation of a cat alarmed them exceedingly; and although they were so exceedingly fond of insects as to dart greedily at crickets and cock-chafers, yet the likeness of a wasp made them suddenly withdraw their little paws. On one occasion while sucking some grapes, one of them happened to squirt a little of the juice into its eye, since which occurrence it never tasted of that fruit without carefully closing the organs of vision, thereby exemplifying the association of ideas. These ouistitis captured and devoured all kinds of flies with the most inconceivable dexterity, but exhibited a strong instinctive fear of wasps,—the French species being at the same time quite different from any they could have ever seen among the foliage of their native forests. They were extremely fond of sugar, eggs, and roasted apples; but they refused all kinds of almonds, acidulated fruits, and such kinds of leaves as are usually eaten as salads. Neither were they fond of flesh; yet if a small living bird was placed within their reach, they immediately captured it, put it to death, and scooped out its brains.

The species are numerous, and are usually divided into two groups,—the Ouistitis properly so called (*Jacchus*, Geoff.), and the Tamarins (genus *Midas* of the French author). To the former belongs the species above alluded to,—to the latter (besides the silky monkey of Shaw), the small and beautiful leonine monkey described by Humboldt.[3] We deem the line of demarcation somewhat doubtful. The distinctive characters are taken chiefly from the incisive teeth. Good figures of the Quadrumana occur in Audebert's great work *Singes et Makis*, fol., Paris, an. viii.

FAMILY II.—LEMURIDÆ.

The second family of the Quadrumanous Order exhibits a nearer approach to the ordinary quadrupedal form than the preceding. Their incisive teeth (never more than eight in the SIMIADÆ), vary in number in different genera. The nostrils are situate at the extremity of the muzzle. The posterior extremities exceed the anterior in length. All the thumbs are well developed, and capable of being opposed in seizure to the fingers, and the fore finger of the hinder hands is furnished with a lengthened claw-like nail. All the other nails all flat. The mammæ, which are pectoral, range from two to four. Tail never prehensile—sometimes wanting. This family is composed chiefly of the genus *Lemur* of Linnæus, and may be said to bear the same relation to that genus, as *Simia* of the same author does to the preceding family,—thus affording another of the numerous proofs which might be adduced of his surprising tact in the formation of natural groups, and of the manner (not seldom unacknowledged) in which he has prepared the great landmarks for posterity.

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[1] The name of Aotus was bestowed in consequence of the erroneous supposition that the animal in question had no external ears.

[2] This highly important distinctive character seems to have been entirely overlooked by the majority of systematic writers.

[3] *Recueil d'Observ. Zool.* p. 14. pl. 5. See also, in addition to the different authors named above, Mikan's *Delectus Floræ et Faunæ Braziliensis*, and the *Diction. Class. d'Hist. Nat.* t. xii. p. 512.

Genus Indris, Lacep. *Lichanotus*, Illiger. Incisive teeth $\frac{4}{4}$, canine $\frac{1-1}{1-1}$, molar $\frac{5-5}{5-5}$; $= 32$. Two pectoral mammæ. Head long, and triangular. Fur woolly.

This genus consists of only two species, both natives of Madagascar, where they were discovered by M. Sonnerat. The best known is the *Indris brevicaudatus* (*Lemur Indri*, Linn.), so called on account of the shortness of its tail. (See Pate II., figures 3 and 3 *a*.) This species is an animal of about three feet long, the general colour of the fur blackish, the face and abdomen grey, the tail, and a spot at its base, dingy white. Its natural habits are little known, although in a state of captivity it is gentle and intelligent, and, when taken young, susceptible of being trained to various useful purposes. If Sonnerat is correct in stating that it is used by the natives of Madagascar, instead of a dog, in the sports of the field, it certainly affords one of the most remarkable examples of the subduing influence of the human race. It is itself a frugivorous creature, an inhabitant of the forest, and a habitual dweller in the tops of trees,—yet under the guidance of man it is induced to assume the nature and propensities of a carnivorous species, and to pursue and capture other living animals. However, we rather doubt the fact. Its voice is said to resemble that of a weeping infant. The other species, distinguished by its lengthened tail, and the yellow colour of its fur, is the flocky lemur of Shaw (*L. laniger*, Gmelin).

Genus Lemur, Lin. Cuv. Incisive teeth $\frac{4}{6}$, canine $\frac{1-1}{1-1}$, molar $\frac{6-6}{5-5}$; $= 36$.[1]

The peculiarities observable in the dentition of this and certain allied genera, may, in the opinion of some naturalists, be thus explained. The six incisor teeth of the lower jaw are long, slender, and almost horizontal, the outer one on each side being, however, larger than the others, and of a somewhat different form. These may therefore possibly represent the canine teeth,—the more especially as the pair usually so considered do not meet those of the upper jaw, but are farther back, and bear much of the character of false molars. If they were to be so regarded, then the dentition of the lemurs would resemble that of the generality of American Quadrumana, which possess an additional molar, but the same number of incisors with those of the ancient continent.

The singular animals known under the name of Lemurs, inhabit the island of Madagascar, where they seem to occupy the place of monkeys, the latter being there unknown. They likewise occur in the not distant island of Anjouan, one of the group of the Comora Archipelago. The ring-tailed species (*L. catta*, Linn.), is one of the most elegant of the genus,—its motions being characterised by a great degree of lightness, its manners mild, its nature very harmless. In size it equals a large cat; the hair is extremely soft and fine, and the tail, which is about twice the length of the body, is marked by numerous alternate rings of white and black. It is gregarious in the wild state, travelling in small troops of thirty or forty. It is easily tamed when taken young, delights in sunshine, but within doors prefers a good place at the fireside to any other quarter. It is frequently brought alive to Europe; and an individual, whose acquaintance we happened to make in France, had lived there for nineteen years. It sometimes sat so near the fire in winter as to singe its whiskers. The white-fronted lemur (*L. albifrons*), has been known to breed in Europe. The ruffed lemur (*L. macaco*, Linn.), is another well known species, remarkable for the extraordinary strength of its voice, which is said to strike with fear and astonishment those who hear it for the first time. It may be likened to that of the Araguata, one of the howling monkeys of America, which fills the lonesome woods of Guiana with its wild and dreadful cries. We have figured *L. ruber* of Peron. (See Plate II., figures 6 and 6 *a*.)

We have few generalities to state regarding the Lemur tribe, for they have been very sparingly observed in their native haunts. They live on trees, feed on fruits, and resemble squirrels in their attitudes. In a domestic state they are gentle, and attached to their friends, but shy of the society of strangers. This shews their good sense.

Genus Loris, Geoff. *Stenops*, Illiger. Teeth as in the preceding, but the molars are provided with sharper points. Eyes large and approximate. Tongue rough. Ears short and furred. Tail wanting, or very short. Four pectoral mammæ.

This genus, as now constituted, contains only two species (*Lem. gracilis* and *tardigradus*, Linn.), both natives of the East Indies.[2] In these animals we perceive an obvious tendency towards carnivorous habits, and a departure from the character of the preceding tribes. They are said to prey very much on insects and birds, and even on the smaller quadrupeds. Their motions are extremely slow, and their mode of life nocturnal. We have represented the species last named on Plate II., figure 4.

Genus Galago, Geoff. *Otolicnus*, Illiger. Incisive teeth $\frac{4 \text{ or } 2}{6}$, canines and molars as in the preceding. Ears large, and naked. Hind legs extremely long. Tail also long. Two pectoral mammæ.

The galagos inhabit Africa and Madagascar. We know little of their natural habits. They live in trees, and are said to feed on insects. The Senegal galago (*G. Senegalensis*, Plate II., figure 7), is called the gum animal by the Moors, probably on account of its occurring so frequently in the forests of gum trees which border the Sahara. It is alleged, however, to eat the gum freely, although there is no doubt of its insectivorous propensities. It is a small animal of the dimensions of a rat, with a very long tail. The species are as yet but ill defined, and Geoffroy has greatly erred in placing the Fennec of Bruce among the galagos.

Genus Tarsius. Storr. Cuv. Incisive teeth $\frac{4}{2}$, canine $\frac{1-1}{1-1}$, molar $\frac{6-6}{6-6}$; $= 34$. Head round, almost spheroidal. Eyes excessively large, and contiguous. Ears long, naked, membranous. Tarsus three times the length of the metatarsus. Nails subulate on both the second and third fingers of the hind feet.

Of the three species which compose this genus, two (*Tarsius Bancanus*, Horsfield, and *T. spectrum*, Geoff.), inhabit the Moluccas, the other (*T. fuscomanus*, Fischer), is a native of Madagascar. Their habits are nocturnal and insectivorous.[3] For their external aspect and teeth see Plate II., figures 5 and 5 *a*.

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[1] The number of molar teeth in this genus is variously stated by different authors. Baron Cuvier gives "six molaires de chaque coté en haut, six en bas."—*Règne Animal*, t. i. p. 107. His brother M. Fred. gives only five for each side on the lower jaw.—*Dens des Mammifères*, p. 24. M. Desmarest assigns five on each side for the upper jaw, but only four on each side for the under. We have stated the number which most coincides with our own observations.

[2] M. Geoffroy St Hilaire (in *Ann. Mus.* t. xix. p. 164), includes the slow lemur of English authors (*L. tardigradus* above named), in his genus *Nycticebus*.

[3] An animal of a very peculiar nature, described as a squirrel by Gmelin, and now forming the Genus *Cheiromys* of naturalists, is placed by some in the Quadrumanous Order. It has, however, only two incisive teeth in each jaw; and we therefore prefer treating of it in a subsequent part of this article, as a member of the Order Rodentia.

ORDER II.—FERÆ.

This order, as now constituted (and corresponding to the CARNASSIERS of Baron Cuvier), contains all the FERÆ, and several of the PRIMATES, of the Linnæan system. The species of which it is composed are characterized by possessing, in common with the Quadrumanous Order, three kinds of teeth, viz. incisors or cutting teeth, canine teeth or tusks, and molar teeth or grinders; but they are distinguished from that order by the different form of their claws, and by never having a flexible thumb opposable to the fingers or toes of either extremity.

The most general attributes of the organic form of the ferine animals are the following: 1*st*, The shortening of the intestinal canal; 2*d*, The increased size and sharpness of the canine teeth, and the cutting or frequently pointed form of the molars; 3*d*, The shortness of the lower jaw, and its peculiar articulation, which (combined with the *locking* of the teeth when closed), is such as to admit only of vertical motion. The term molar or grinding, therefore, cannot with accuracy be applied to the lateral or posterior teeth of strictly carnivorous animals, which masticate their food by biting it in pieces, but cannot triturate or grind it like the purely herbivorous kinds.[1] 4*th*, The double convexity of the zygomatic arch of the temporal bone, and the depression of the parietal towards the axis of the head, to afford space for the insertion of the temporal-maxillary muscles, of which the bulk increases with what may be called the *carnivority*. Characters deduced from the size or even form of the claws are of less avail,—seeing that both the power and dimensions of these parts are increased in most of the Edentata, among which the organization of the teeth and jaws follows an inverse proportion. In the cat-kind, however, the shape of the claws is extremely characteristic.

The degree of each of the four anatomical characters above alluded to, and their combination, more or less complete, determine the degree of carnivority,—with which that of ferocity usually corresponds. We must not, however, attach to the word ferocity the idea of any fatal or irresistible necessity to murder,—for the instinct to destroy is only the sensation of hunger in animals having a propensity to flesh, and provided with the means of obtaining it. It requires, indeed, a little more determination and activity, with, it may be, more malignity of movement, for one animal to seize upon and devour its neighbour, than for another animal to masticate a turnip,—but each is acting in obedience to its natural instincts, and neither is following the dictates of a depraved appetite.

As in all other great groups, we have here various modifications of the typical character. Several bats are frugivorous, though in their general structure too closely allied to their congeners to be removed from the ferine order; while various bears and badgers are extremely accommodating in their dispositions, and will eat freely enough of vegetable substances rather than starve. The general form and aspect of this order are also highly varied. Some are organised for flight, as the Cheiroptera; others for swimming and diving, as the seals and morses; while several are subterranean, as the moles. We do not find such a diversity in the sphere of existence among the pachydermatous and ruminating tribes. The geographical distribution of the order is unlimited, so that we cannot connect flesh-eating propensities in any way with climate. If the lion and the tiger haunt habitually the torrid zone, the polar bear,

> "With dangling ice all horrid, stalks forlorn"

along the frost-bound shores of Greenland. Thus heat and cold have no more influence over the nutritive appetite, than over the warmth of the instinct of love,—which rules supreme alike amid perennial snows, and beneath the unmitigated glare of equatorial suns.

We arrange the genera of the Ferine Order under four principal divisions, viz. CHEIROPTERA, INSECTIVORA, CARNIVORA, and MARSUPIALIA.

DIVISION I.—CHEIROPTERA.

The most remarkable and striking peculiarity of this group consists in the membranous expansion which pervades the sides of the body, connecting the anterior and posterior extremities, and, in many cases, the latter, with the tail. This structure enables almost all the species to fly like birds, although with less activity and power; and the exercise of such a function of course requires a modification of other parts, such as great strength of clavicle and breadth of shoulder-blade, for the production of the requisite solidity. It is, however, incompatible with the rotation of the fore-arm, which would have enfeebled the force of the flying action.

The Cheiropterous division is composed of two families, the VESPERTILIONIDÆ and the GALEOPITHECIDÆ.

FAMILY 1ST.—VESPERTILIONIDÆ, OR BATS.

In this family the fore-arms and fingers are excessively elongated, and the interstices of the latter being filled up by the membrane already alluded to, which also extends backwards to the hind feet, genuine wings are thus provided, more expansive even than those of birds. The pectoral muscles are extremely thick, and the sternum has a central ridge for their attachment, resembling that of birds. The thumb is short, and armed with a hooked nail, by means of which the species climb or suspend themselves. Their hind feet are rather feeble, furnished with five toes, almost always of nearly equal size, and armed with pointed and sharp-edged nails. The eyes are proportionally very small, but the external ear is usually very large, partaking, as it were, of the expansive nature of the lateral membrane, and in common with it is naked, or nearly hairless. This membrane, whether in the form of auricle or wing, is supposed to be endowed with a very exquisite perceptive power—sufficient to guide the flying creature through labyrinths of subterranean darkness, and even, according to Spallanzani, to wing its intervening way through various obstacles, after it has been totally deprived of sight. This power is presumed to result from the perception, by the nerves of the cutaneous system, of the refluxes of air from near opposing bodies.

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[1] There seems to be no very satisfactory or explicit nomenclature of the teeth of ferine animals. False molars, carnivorous cheek-teeth, and tubercular grinders, are probably the most precise and applicable terms which can be employed to discriminate the different kinds of molar teeth, commonly so called, which distinguish the family Carnivora; and these terms have the additional advantage of corresponding closely with the nomenclature proposed by M. Fred. Cuvier, and adopted by his illustrious brother in the *Règne Animal.* In the Genus *Felis*, for example, there are four molar teeth in the upper, and three in the under jaw. Of these the two anterior, both above and below, are the most cutting, and are called the false molars (*fausses molaires* of Cuvier). They are followed by a very large tooth, which, in the upper jaw, is furnished with three points or lobes, in the under with only two. This is the carnivorous cheek-tooth (*carnassière*). Behind it, in the upper jaw, is a small flattish tooth (*la tuberculeuse*), which may be named the tubercular grinder. In animals of the cat kind there is no corresponding separate tooth of the last description in the lower jaw; but its function is performed by the inner projecting lobe of the under carnivorous cheek-tooth, the rounded point of which, when the jaws are closed, is applied to the flat surface of the upper tubercular grinder. In the canine race, however, there are two tubercular teeth on both sides of either jaw, and it is with these that they chew the grass which they so frequently swallow. In the tribe of bears the false molars, instead of being more or less compressed and cutting, are entirely tuberculated; and, in perfect accordance with this structure, they are known to be the least carnivorous of the family to which they belong: indeed, the disposition and habits of an animal may be correctly deduced from the greater or less prevalence of the cutting or tuberculated character of the molar teeth.

Bats are nocturnal, or at least twilight loving animals, which in northern countries pass the winter in a state of lethargic repose. From this state of hybernation, however, they are easily roused, and it is no uncommon thing to see our smaller species flitting about in a winter afternoon, during the occurrence of a milder day than usual. However, the then almost total absence of moths and flies must render such occasional excursions on the whole enfeebling, by exciting the digestive and other functions (previously at rest), without, at the same time, affording the means of sustentation. During the day they hang suspended from the roofs of barns and other buildings, or in crevices of ruined castles, or find shelter beneath the murky canopy of caves, or the overhanging gloom of shaded rocks. Neither do they despise the secure concealment afforded by the hollow chambers of ancient forest trees, whether rent by the "red lightning's glare," or yielding imperceptibly to slow decay. They usually produce two young at a birth, which adhere tenaciously to their mother, and are frequently borne about by her during her twilight flights.

The species (including the various genera, of which our narrow limits will enable us to give but a brief account), are extremely numerous,—above 130 different kinds being known to naturalists. The majority inhabit the regions within the tropics, and none occur in the countries of the extreme north; neither are we aware that any have yet been observed in New Holland. When the "knell of parting day" announces the approach of the long continuing twilight of our temperate regions, we see our own diminutive species flitting about on leathern wings, or dimpling the surface of the still waters, in search of insects or other natural prey; but these give us but a feeble idea of the monstrous forms which inhabit equatorial countries. Many of the genera are extremely circumscribed in their geographical distribution, either owing to their nocturnal habits, or their powers of flight being unequal to a long sustained migration. We may add, that all bats possess four well developed canine teeth, but that the incisors differ in number in the various genera. Of a few of these we shall endeavour to exhibit the principal characteristics.[1]

GENUS PTEROPUS, Brisson, Cuv. Incisive teeth $\frac{4}{4}$, canine $\frac{1-1}{1-1}$, molar $\frac{5-5}{6-6}$; $= 36$. Form of the incisors conical; canines rather large; molars with the crown obliquely truncated, and marked by a longitudinal groove. Head long and conical. Ears short, simple, and without any tragus.[2] No peculiar appendages upon the nose. Tail short or wanting. Interfemoral membrane deeply incised. The index finger, with three phalanges and a rudimentary nail. The tongue papillose. (See Plate III., figures 4 and 6.)

The species of this genus, called *Roussettes* by the French, are of a frugivorous regimen, feeding on pulpy fruits, especially bananas. They are confined to the ancient world,—occurring chiefly in the islands of the Indian Archipelago, Bengal, Madagascar, the Isle of France, and several parts of Africa. They are the largest of all the bat tribe, and certain species measuring between five and six feet from tip to tip of the extended wings.

The eatable roussette (*Pt. edulis*) is of a blackish colour, deeper on the breast than back. It is a large species, measuring about five feet in extent;—the body sixteen inches long. Its flesh is white and delicate, and is held in great esteem as an article of food by the natives of the Island of Timor. It seems to vary in its external character with age, and has been accordingly described under different names. Thus the *Kalong* of the Javanese (*Pt. Javanicus*, Horsfield) is regarded as identical. It is a gregarious species, very abundant in the lower parts of Java. "Numerous individuals," says Dr Horsfield, "select a large tree for their resort, and suspending themselves with the claws of their posterior extremities to the naked branches, often in companies of several hundreds, afford to the stranger a very singular spectacle. A species of ficus, in habit resembling the Ficus religiosa of India, which is often found near the villages of the natives, affords them a very favourite retreat, and the extended branches of one of these are sometimes covered by them. They pass the greater portion of the day in sleep, hanging motionless: ranged in succession, with the head downwards, the membrane contracted about the body, and often in close contact, they have little resemblance to living beings, and by a person not accustomed to their economy, are readily mistaken for a part of the tree, or for a fruit of uncommon size suspended from its branches. In general these societies preserve a perfect silence through the day; but if they are disturbed, or if a contention arises among them, they emit sharp piercing shrieks, and their awkward attempts to extricate themselves, when oppressed by the light of the sun, exhibit a ludicrous spectacle. In consequence of the sharpness of their claws, their attachment is so strong that they cannot readily leave their hold, without the assistance of the expanded membrane; and if suddenly killed in the natural attitude during the day, they continue suspended after death. It is necessary, therefore, to oblige them to take wing by alarming them, if it be desired to obtain them during the day. Soon after sunset they gradually quit their hold, and pursue their nocturnal flights in quest of food. They direct their course, by an unerring instinct, to the forests, villages, and plantations, occasioning incalculable mischief, attacking and devouring indiscriminately every kind of fruit, from the abundant and useful cocoanut, which surrounds every dwelling of the meanest peasantry, to the rare and most delicate productions, which are cultivated with care by princes and chiefs of distinction. By the latter, as well as by the European colonists, various methods are employed to protect the orchards and gardens. Delicate fruits, such as mangos, jambus, lansas, &c., as they approach to maturity, are ingeniously secured by means of a loose net or basket, skilfully constructed of split bamboo. Without this precaution, little valuable fruit would escape the ravages of the kalong.

"There are few situations in the lower parts of Java in which this night wanderer is not constantly observed. As soon as the light of the sun has retired, one animal is seen to follow the other at a small but irregular distance, and this succession continues uninterrupted till darkness obstructs the view. The flight of the kalong is slow and steady, pursued in a straight line, and capable of long continuance. The chase of the kalong forms occasionally an amusement to the colonists and inhabitants during the moonlight nights, which, in the latitude of Java, are un-commonly serene. He is watched in his descent to the fruit-trees, and a discharge of small shot brings him readily to the ground. By this means I frequently obtained four or five individuals in the course of an hour, and by my observations I am led to believe that there are two varieties which belong to one species, as they appear all to live in one society, and are obtained promiscuously."[1]

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[1] The student who desires a detailed acquaintance with the Cheiropterous tribes, will study with advantage the systematic exposition given by M. Desmarest, in his *Mammalogie*, and M. Geoffroy St Hilaire's papers in the *Annales du Mus.* The English reader is referred to Mr Griffith's Translation of the "Animal Kingdom," (particularly the *Supplementary Essay*, vol. ii. p. 84, and *Synopsis*, vol. v. p. 54).

[2] We apply the term *tragus* to that secondary leaf-like expansion, which in many bats covers or protects the auricular opening. It is the part named *oreillon* by the French writers.

A roussette (we know not the exact species) brought alive to France about the beginning of the present century, was observed to remain constantly calm and motionless throughout the day, suspended by one of its hind feet. Yet Quoy and Gaimard report that they saw these great bats flying during the day in the Carolina Islands, and Messrs Lesson and Garnot have made the same remark as to their diurnal powers. These notices are the more interesting, as they confirm the statements of the earlier voyagers.

The vampire bat, commonly so called, (*Vespertilio vampyrus*, Linn.,) belongs to the genus Pteropus. Having already alluded to the frugivorous habits of the species, we need scarcely add, that the specific name is greatly misapplied. A vampire is an imaginary monster, the chief amusement of which was supposed to consist in sucking the blood of sleeping persons, and the superstition, however absurd, must have been sufficiently fearful to those who gave it credit, as many did in Poland and Hungary about a hundred years ago. Some vague allegations having been made regarding the blood-sucking propensities of certain bats, Linnæus bestowed the name of *vampyrus* on a large species found in Madagascar. This was unfortunate, as the actual blood-sucking bats inhabit South America, and belong to another group, which now forms the genus *Phyllostoma*.

The other frugivorous genera allied to Pteropus in their habits are PACHYSOMA, MACROGLOSSUS, CEPHALOTES, and HYPODERMA.

GENUS MOLOSSUS, Geoff., Cuv., Desm. Incisive teeth $\frac{2}{2}$, canine as usual, molar $\frac{4-4}{5-5}$; $= 26$. The upper incisives are of medium size, bifid, convergent, and slightly separate from the canine; the lower very small, as if pressed together in advance of the canines, and each terminated by two minute points. The upper canines are large; the under touch each other at the base, their points projecting outwards. The molars are large, and their crowns furnished with several sharp points. The head is large, the muzzle broad, the nostrils slightly projecting, opening forward, and provided with a little pad. The ears are large and united, and provided with a small tragus. No appendages to the nose. Tongue smooth. Interfemoral membrane narrow, and terminating rectangularly. Tail long, usually half enveloped at the base, the point free.

The species of this genus, of which about a dozen are known to naturalists, occur both in the Old World and the New. The majority, however, are natives of South America. We have no detailed information regarding their habits of life. In these, however, they are supposed to coincide with the bats of Europe. We suspect that even the characters of the teeth are imperfectly described. A pair of incisors in each jaw is rather an anomalous character for an insect-eating genus, and M. Temminck has stated his belief that several species have at first six in the lower jaw, of which four are successively dropped.

We shall merely in this place name the genera NYCTONOMUS of Geoffroy, of which, though one occurs in Brazil,[2] the species are characteristic of the Old World, and DYNOPS of Signor Savi, of which the typical species was some years ago discovered in the neighbourhood of Pisa.[3]

GENUS NOCTILIO, Linn., Cuv. Incisives $\frac{4}{2}$, canines as usual, molars $\frac{4-4}{4-4} = 26$. The central upper incisives are the largest; the inferior are placed in advance of the canines; the canines are very strong. The crowns of the molars are furnished with sharp tubercles. See Plate III., figure 3. The muzzle is short, inflated, cleft, and covered with warts or fleshy prominences. The nose is confounded with the lips. The ears are small, lateral, isolated; the tragus internal. The interfemoral membrane is very large and salient. The tail is of medium size, or rather short, and partly enveloped, partly free, and placed above the membrane. The claws of the hinder extremities are extremely strong.

The species are but few in number, and, as far as yet known, are natives of South America. They are sometimes denominated hare-lipped bats. The Peruvian bat of Pennant (*N. leporinus*) may be named as an example. See its cranium as above referred to.

GENUS PHYLLOSTOMA, Cuv., Geoff. Incisive teeth $\frac{4}{4}$, canine $\frac{1-1}{1-1}$, molar $\frac{5-5}{5-5}$ or $\frac{5-5}{6-6}$; $= 32$ or 34. The incisors have often the appearance of being closely pressed between the canine, the lateral being very small; the canines are frequently very large at their base. The head is large, and somewhat uniformly conic; the gape deeply cleft. The nose supports two membranous crests, the one leaf-like, the other in the form of a horse-shoe. The ears are large, naked, disunited. The tragus is internal, dentated, and growing from the margin of the auricular cavity. The eyes are very small and lateral. The tongue, capable of considerable extension, is beset at its extremity by corneous papillæ. The middle anterior toe has an additional phalanx. The tail varies in size, and is wanting in certain species. The interfemoral membrane likewise varies in its degree of development.

The singular creatures which constitute our present genus are believed to be peculiar to South America, where, however, they are distributed over a considerable extent of territory, from the Isthmus of Darien to Paraguay. The incisive teeth vary in number even in the same species, some of those in the lower jaw being frequently pushed out by the growth of the canines, and in different species the amount of molar teeth is dissimilar. The papillæ of the tongue above alluded to, in connection with tubercles symmetrically arranged around the mouth, bestow on several species a strong power of suction, which they frequently exercise to the disadvantage of their neighbours, by withdrawing the life-blood from man and beast. These are the famous *vampires*, of which various voyagers have given us such redoubtable accounts, and which are known to have almost entirely destroyed the first establishment of Europeans in the New World. Although they extirpated the cattle at Borgia, and elsewhere, they also feed on insects, after the manner of other bats, and according to Azzara do not venture to attack the cattle, unless when driven to extreme hunger by a deficiency of other food. The structure of the tongue is remarkable. It is about six times longer than broad, flattish above, rounded beneath, the surface slightly shagreened, and close to the extremity there is a peculiar cavity, the centre of which is marked by a raised point, and the circumference by eight warts.

The molar teeth of the spectre bat, or true vampire (*Vesp. spectrum*, Linn.), are of the most carnivorous character, the first being short and almost plain, the others sharp and cutting, and terminating in three or four points but it does not appear that it makes use of them while attacking the larger kinds of prey, trusting rather to its subtle and insidious tongue, for by no other means could it perforate the skin of a sleeping animal, without causing so much pain as to speedily arouse it from its slumbers. Now we know that the sleep of the victim is scarcely ever interrupted, though we cannot vouch for the fact that this is effected, as some of the older voyagers allege, by the fanning motion of the wings of the bat producing a *delicious coolness*, which renders repose the deeper, "till the sufferer awakens in eternity." There is no doubt, however, that the accounts given by Pietro Martyro, Ulloa, and Condamine, though perhaps stated with some circumstances of exaggeration, are substantially correct. They have been confirmed by Azzara, an accurate and discriminating naturalist of modern times. "The species," says that observer, alluding to the Phyllostomata, "with a leaf upon the nose, differ from the other bats, in being able to turn, when on the ground, nearly as fast as a rat, and in their fondness for sucking the blood of animals. Sometimes they will bite the crests and beards of the fowls while asleep, and suck the blood. The fowls generally die in consequence of this, as a gangrene is engendered in the wound. They bite also horses, mules, asses, and horned cattle, usually on the buttocks, shoulders, or neck, as they are better enabled to arrive at these parts from the facilities afforded by the mane or tail. Nor is man himself secure from their attacks. On this point, indeed, I am enabled to give a very faithful testimony, since I have had the ends of my toes bitten by them four times, while I was sleeping in cottages in the open country. The wounds which they inflicted, without my feeling them at the time, were circular, and rather elliptical; their diameter was trifling, and their depth so superficial as scarcely to penetrate the cutis. It was easy, also, on examination, to perceive that these wounds were made by suction, and not by puncture, as might be supposed. The blood that is drawn, in cases of this description, does not come from the veins, or from the arteries, because the wound does not extend so far, but from the capillary vessels of the skin, extracted thence, without doubt, by these bats, by the action of sucking or licking it.[1]"

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[1] *Zoological Researches.*

[2] *Annales des Sciences Nat.*, Avril 1824.

[3] *Giornale dei Letterati*, No. 21, p. 230.

The species are numerous, and have been formed into sectional groups or subgenera by some recent writers,—chiefly in accordance with the presence or absence of the tail.

We must here pass over, without any special notice, the genus GLOSSOPHAGA, Geoff., which contains species allied in their habits to those last named, but distinguished by a longer, more extensile tongue, and other characters.

GENUS MEGADERMA, Geoff. Cuv. Incisive teeth $\frac{0}{4}$, canine as usual, molar $\frac{4-4}{5-5}$; $=26$. Ears very large and united. Tragus also much developed. Nose furnished with three appendages,—one erect, one horizontal or foliaceous, and a third like a horse-shoe. Tail wanting. Interfemoral membrane square. Third finger without the first phalanx. Tongue smooth and short.

The species of this genus, though few in number, are spread over a considerable extent of territory,—being found in Java, the island of Ternate, and along the coast of Senegal. We are not aware that naturalists have acquired any precise knowledge of their habits, except by induction from those of their congeners. They dwell in forests, and are remarkable for the great extent of their membranous expansions. One of their most singular organic characters consists in the absence, or at least rudimentary state of the intermaxillary bone, which of course entails with it the non-existence of the incisive teeth. It may be inferred, however, rather that the bone is small, inconspicuous, and suspended in the cartilage, than entirely wanting.

GENUS RHINOLOPHUS, Geoff. Cuv. Incisive teeth $\frac{2}{4}$, canines as usual, molars $\frac{5-5}{5-5}$; $=30$. The upper incisors are very small, separate, and frequently fall out; the lower are bilobed. The canines are of medium size,—the crowns of the molars jagged with extremely sharp points. The ears are of moderate size, lateral, and isolated. The expansion called the tragus is non-existent, or rather is replaced by an exterior lobe of the ear. The interfemoral membrane is large, and entirely envelopes the tail, which is long.

This genus includes some European species which we distinguish by the name of *horse-shoe bats*, in reference to the form of the appendage on the muzzle. They hang suspended during the day from the roof of caverns, and fly about in the evening twilight, preying on moths and other insects. We shall here name only the largest of the British species, *R. ferrum equinum*, which is well known in the south of England. (See Plate III., figure 1.) It is of a pale rufous brown colour, and its wings extend nearly fifteen inches.

GENUS NYCTERIS, Cuv. Geoff. Incisive teeth $\frac{4}{6}$, canines as usual, molars $\frac{4-4}{4-4}$; $=30$. The upper incisors are bilobed, and contiguous; the under trilobed. There is a deep longitudinal furrow down the muzzle, apparent even on the cranium, and margined, and partly covered, by a fold of the skin.

The species occur in Africa and Java, and are remarkable for the following peculiarities of structure. The nostrils are habitually closed, and require an act of volition to be put in communication with the external air, and the species, it is supposed, are thus enabled to establish themselves in subterranean chambers or other places, where their congeners would be destroyed by pestilential vapours. The skin forms as it were a sack around the body, with which it has scarcely any adherence, except at certain points, where there are some cellular attachments. At the bottom of each of the cheek pouches there is a small aperture communicating with this pervading sack, and by means of which the latter is filled and inflated with air, so that the creature becomes immersed in air, or surrounded as it were by a muff of that elastic fluid. The tail is terminated by a cartilaginous bifurcation, resembling the form of the letter T.[2]

Passing unwillingly over the genera RHINOPOMA, TAPHOZOUS, and MYOPTERIS of Geoff. St Hilaire, we reach the

GENUS VESPERTILIO of modern authors. Incisive teeth $\frac{4}{6}$, canine $\frac{1-1}{1-1}$; molar $\frac{4-4}{5-5}$ or $\frac{5-5}{6-6}$; $=32$ or 36. The upper incisors, pointed and cylindrical, are disposed in pairs; the under close together, inclined or projecting forwards, their edges bilobed. The canines are of moderate size, and do not touch each other at their base. The anterior molars are simply conical; the posterior have broad crowns beset with points; the lower ones are grooved on their sides; the upper, which are twice as broad, have crowns with an oblique edge. The nose has no membranous appendages; it is neither grooved nor furrowed, and the nostrils are destitute of opercles. The under lip is simple; the tongue smooth, not protractile. The ears, more or less extended, possess a tragus. The wings are of great proportional extent. The index finger has only one phalanx, the middle three. the annular and little finger only two. The interfemoral membrane is very large, and entirely includes the tail. The fur is soft and thick.

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[1] *Essai sur l'Hist. Nat. du Paraguay*, T. ii. p. 273.

[2] See the *Memoires de l'Institut d'Egypte. Hist. Nat.*, t. ii. *Mem. sur les Cheiroptères.*

Feræ. Cheiroptera.

This extensive genus includes between thirty and forty species, some of which occur in every quarter of the globe, although they may be stated as rather characteristic of temperate regions. Most of the European Cheiroptera pertain to the restricted genus *Vespertilio*, such as the *V. murinus* of naturalists, recognisable by its oblong ears equalling the head in length, with their tragus semicordate. The great bat or noctule (*V. noctula*), of which the ears are shorter than the head, and triangular, and the nostrils bilobate, inhabits England (see Plate III., figure 2), as do likewise the *pipistrelle* and several others not yet discovered in the northern quarters of the island. The eared bat (*V. auritus*, Linn.), is a much more common species. It belongs to the genus *Plecotus*, Geoff. distinguished by the large ears which unite with each other at the base, above the cranium. (See Plate III., figure 7.) Altogether we have about thirteen different kinds of bat in Britain. We shall here terminate our brief view of the Vespertilionidæ; —“ Et nous devons faire observer ici,” we may add, in the words of Baron Cuvier, “ qu'il n'est point de famille qui ait besoin plus que celle des chauves-souris d'une revue faite sur nature et non par voie de compilation.” [1]

Family 2d.—GALEOPITHECIDÆ.

Fore arms and fingers not attenuated and extended as in bats, but furnished with curved claws. Lateral membrane not bare, as in the animals last named, but covered on both surfaces by close-set hair.

Genus Galeopithecus, Pallas. Incisive teeth $\frac{4}{6}$, canine $\frac{1-1}{1-1}$, molar $\frac{6-6}{5-5}$; $= 36$. Upper incisives very small, the lateral lengthened, compressed, cutting, with a small tubercle on each side at the base. Lower incisives inclined, and divided like the teeth of a comb; the intermediate being composed of eight laminæ, the second on each side of nine, the outermost of three or four (see Plate III., figure 8). The upper canines are very small, compressed, sharp-pointed, broad at the base; the lower are of larger size. The upper anterior molars resemble the canines, the posterior have their crowns beset with points. The muzzle is pointed. The ears are small and rounded; the fingers short, with a broad palm, and furnished with strong curved claws.

The animal known under the name of flying lemur (*Lemur volans*, Linn.), may be named as an example of our present genus. It is the *Galeopithecus rufus* of modern systems. (See Plate III., figure 5.) This species measures about a foot in length, and is of a greyish-red colour, varying with age. It inhabits the Moluccas and the isles of Sunda, and seems to be the only species distinctly known, though two others are named in systematic works. These animals are nocturnal, living on fruits and insects, and suspending themselves by their hind legs, after the manner of bats. Yet they differ greatly from all the latter in the form of the fore paws, and the presence of claws on all the fingers. Although an ample membrane extends from the sides of the neck to those of the tail, it is useful rather as a parachute, by enabling them to spring or descend from branch to branch, than for the purposes of a sustained or continuous flight. The hind feet are equally palmated with the anterior, and in each the claws alone are free. The membrane, moreover, differs from that of bats, in being clothed on both sides with short dense hair. The species above named is called *olek* by the natives of the Pellew islands, who hold it in great esteem as food, notwithstanding that it smells extremely like a fox. It is capable of running on the ground, and is said to climb trees like a cat.

Feræ. Insectivora.

The position of the genus Galeopithecus is, in truth, as yet but ill determined in our systems. It seems, however, improper to remove it far from the vicinity of the bats and lemurs. Some authors, indeed, combine it with the latter, as a family of the quadrumanous order; while others extend that order, so as to include within its range the whole of the cheiropterous tribes.

DIVISION II.—INSECTIVORA.

The animals comprising this division, though dissimilar to the preceding in their general form and aspect, resemble them in several particulars, especially in the conical points of the molar teeth. They are also for the most part nocturnal, and of darkling habits, and exhibit an additional analogy in their tendency to hybernation during the colder months. They are furnished with clavicles, but do not possess the extended lateral membrane of the cheiropterous genera. Their legs may be characterized as short, and their locomotive powers as somewhat defective. The mammæ, instead of being pectoral, as in the preceding tribes, are placed beneath the abdomen. The teeth vary so greatly in the different groups, that no generalities can be deduced regarding them.

Tribe 1st.

Two long incisives in front, followed by other incisives, and small canines, shorter than the molar teeth.

Genus Erinaceus, Linn. Incisive teeth $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molar $\frac{5-5}{4-4}$; $= 34$. Upper intermediate incisives very long, separate, cylindrical, directed forwards; the inferior inclined. Canines smaller than the molars. Body covered laterally and above with prickles, beneath with stiffish hairs.

The species of this genus commonly called hedgehogs, are few in number, and confined to the ancient continent. We need not describe the well known British species (*E. europæus*, see Plate III., figure 9), a timid nocturnal creature, which feeds on snails, earth-worms, and insects. It has also been accused of injuring eggs and poultry. It is easily tamed, and is nearly omnivorous in confinement. According to Pallas, it devours the cantharis or blistering beetle with impunity. It has also been said to resist large doses of prussic acid. The female, about the beginning of summer, brings forth from three to five young, which are at first blind, almost white, and nearly naked, although the germs of the prickles are observable. Both young and old pass the winter in a state of profound lethargy. The hedgehog occurs over the whole of Europe, except the extreme north.

Genus Sorex, Linn. Central incisive teeth $\frac{2}{2}$, false canines or lateral incisives $\frac{3-3}{2-2}$, or $\frac{4-4}{2-2}$, true molars $\frac{4-4}{3-3}$; 28 or 30. The central upper incisives are hooked and dentated at the base; the lower are elongated and projecting. The false canines, especially the upper, are much less than the central incisives. The molars have broad crowns beset with points, the upper being the largest, their cutting edge oblique. The head is very long, the nose lengthened and moveable. The ears are short and rounded. The eyes small but perceptible. The body is covered by fine short hair.

This genus consists of the small subterranean creatures called Shrews. The nomenclature of their teeth is a disputed point among naturalists. They are remarkable for certain odoriferous glands along their flanks, and, according to Geoffroy St Hilaire, for the non-existence of the optic nerve; yet nobody doubts that they can see. Shrews viewed generically, may be said to be cosmopolites, in so far as they are distributed over almost all the earth; and it is even said, that certain species occur both in Europe and America. They vary in their habits of life, some attaching themselves to dry situations, while others prefer moist meadows, and the margins of springs and quiet streams. They prey chiefly on insects, and are themselves often killed, but seldom eaten, by cats. However, owls make amends for this omission by swallowing them greedily. It is believed that even the European species are still but incompletely known, their extremely minute size enabling them to avoid the notice of naturalists. They are probably the smallest of all quadrupeds, at least we are inclined to presume so from the recorded dimensions of some of those recently described by Lichtenstein and Savi.

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[1] *Règne Animal*, t. i. p. 122.

The most abundant species with us is the *Sorex araneus*, or common shrew. It measures about 2½ inches in length, without the tail, which is a third shorter than the body, and of a square form. The teeth are white, the ears naked and exposed. It is subject to a frequent epidemic in the autumn season, and presents one of the few instances we meet with, of an animal in a state of nature being found dead, without any apparent injury. The water shrew (*Sorex fodiens*) is somewhat larger than the preceding. It is of a blackish colour above, whitish beneath, the tail about a fourth less than the body in length, and compressed towards the end. The incisive teeth are red at the base, and the ears are in great measure concealed within the fur. There are many foreign species not, however, as yet distinctly characterised; and the learned antiquary Passalacqua informs us that he met with more than one species embalmed in a tomb of the Necropolis of Thebes. One of these was evidently, from its great size, and other characters, identical with *Sorex giganteus*, a species which, in the living state, occurs only in India. This is a fact interesting alike to the archæologist and the natural historian, as it leads to the belief, either that certain species of animals native to Egypt in ancient times, no longer occur in that country, or that the Egyptians derived from India some of the objects of their religious worship.

We may here name the TUPAIA of Raffles and Horsfield (*Sorex glis*, Diard., *Cladobates*, F. Cuvier), a new generic group from the Indian archipelago, of which the teeth agree with those of the Insectivora, although the habits of the species differ in this respect, that they prey like the Quadrumana among the branches of trees.[1] Their exact location in the system is therefore still somewhat doubtful.

GENUS MYGALE, Cuv. Differs from Sorex in having two very small teeth between the larger of the lower incisives, and in the upper incisives being triangular and flattened. Behind these incisives are six or seven small teeth, and four jagged molars.

Pallas and Geoffroy St Hilaire differ in their descriptions of the dentition of the species they have respectively described. These animals are of aquatic habits, dwelling in holes to which they enter under water, and then proceed upwards to dry and comfortable quarters. They feed on larvæ and worms, and, according to some authors, on the roots of the nymphæa. The fur of the Russian species (*M. Moscovita*, Geoff., *Castor moschatus*, Linn.) is much esteemed, on account of its being composed, like that of the beaver, of long silky hair, and of a softer felt beneath. It exhales a strong musky odour, which imbues the flesh of pike and other voracious fish which prey upon it. We are acquainted with only two species, that of Russia just named (extremely abundant in the environs of Woronech, where it is often entangled in the nets of the fishermen), and the *Desman* of the Pyrenees (*M. pyrenaica*). It is said that these creatures, not being torpid in winter, suffer dreadfully during that inclement season, from the freezing of the waters. Many perish from suffocation in their subterranean abodes,—these having no communication with the external air. The species last named has as yet been found only in the neighbourhood of Tarbes at the foot of the Pyrenees.

GENUS SCALOPS, Cuv. The teeth of this genus resemble those of the preceding, but their false molars are less numerous.

The only known species is the shrew mole (*S. canadensis*), a North American animal, nearly eight inches in length, with a thick cylindrical body, no apparent neck, short concealed limbs, and broad strongly nailed hands. It resembles the European mole in its habits, leading a subterranean life, forming galleries, and feeding principally on grubs and earthworms. According to Dr Godman, they exhibit the singular custom of coming to the surface daily exactly at the hour of noon, and may then be taken alive by thrusting a spade beneath them, and throwing them out of their burrows. A tame one in the possession of Mr Peale was very lively and playful, would follow the hand of its keeper by the scent (the eyes are very inefficient), and fed freely on fresh meat, whether cooked or raw. It would burrow for amusement in loose earth, and after making a small circle, would return spontaneously to its keeper. Although widely spread over North America, Dr Richardson does not think its existence probable beyond the 50th degree of latitude, at least to the eastward of the Rocky Mountains, because the earth-worm, its favourite food, is unknown in the countries of Hudson's Bay.[2]

GENUS CHRYSOCHLORIS, Cuv. Incisive teeth $\frac{2}{4}$, conical teeth $\frac{3-3}{3-3}$, molar $\frac{6-6}{5-5}$; $= 40$.

The only species distinctly ascertained to belong to our present genus, is the *C. capensis* (*Talpa asiatica*, Gmelin), commonly called the Cape Mole, an animal somewhat less than the mole of Europe, of a brownish colour, but remarkable for exhibiting (especially when moistened) beautiful metallic reflections of a green and copper colour. This burnished aspect is extremely rare among the mammiferous tribes. The species in question inhabits the Cape of Good Hope (not Siberia, as erroneously indicated by Seba), where it is found to be troublesome in gardens. It is subterranean and insectivorous, and differs from the true talpæ in having only three claws to the fore-feet.[3] Its eyes are almost obsolete. We have represented this singular animal on Plate IV., figure 2.

TRIBE 2D.

Two large upper incisors in front, followed by two others on each side, of which the first has the form of a canine; canines, properly so called, small, and not distinct from the false molars; four lower incisors inclined forwards, and spoon-shaped.

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[1] *Linn. Trans.* vol. xiii. p. 257; and *Horsfield's Zoological Researches*, fascic. 3.

[2] *Fauna Boreali-Americana* (the Quadrupeds, by Dr Richardson), Part I. p. 11.

[3] "Ceux de derriere en ont *cinq* de grandeur ordinaire." Cuvier, *Règne Animal*, t. i. p. 129. "Pieds de derriere à *quatre* doigts." Desmarest, *Mammalogie*, p. 156.

Feræ. Insectivora.

Genus Condylura, Illiger. Incisives $\frac{6}{4}$, conical teeth, or false molars $\frac{3-3}{5-5}$, true molars $\frac{4-4}{3-3}$; $= 40$.[1]

The snout in this genus is greatly prolonged, and is generally terminated by a radiated expansion, from which the name of star-nose has been applied to it. The species, of which only two or three are known to naturalists, greatly resemble moles in their manners and aspect. They have hitherto been found only in North America. We have figured the *Cond. cristata* of Desm. or "radiated mole" of Pennant. (See Plate IV., figures 1 and 1 *a*.)

Tribe 3d.

Four canines, apart,—between them small incisives.

Genus Talpa, Linn. Incisives $\frac{6}{8}$, canine $\frac{1-1}{1-1}$, molar $\frac{7-7}{6-6}$; $= 44$.

We need scarcely describe the external aspect of an animal so well known as the common mole (*T. europæa*), almost the only species of which the restricted genus *Talpa* is now composed.[2] There are few species, however, of greater interest to the naturalist, whether he regards their singular economy and instinctive habits, or their very peculiar organic structure. Moles present as it were the type or perfect form of a subterranean dweller. The snout is pointed, yet strong and flexible, the head somewhat depressed, the eyes inconspicuous, the external ears wanting, the cervical ligament unusually strong, the bones of the anterior extremity angular, and so extremely thick as to be almost as broad as they are long. The two bones of the fore-arm are fastened together, the paws are broad and shovel-shaped, with strong claws, and an elongated bone of the carpus communicates great solidity to their under edges. The clavicles are very powerful, and the motive muscles of the anterior extremity, especially the pectorals, are enormous. Although the organs of sight are feebly developed (they suffice, however, for whatever visual perceptions may be necessary to an almost constant dweller in subterranean darkness), the senses of hearing, touch, and smell, are acute.

The galleries of the mole are constructed with admirable sagacity and art, and the female brings forth in a dry and sheltered chamber, well furnished with grass and leaves. The exact period of gestation is unknown, but as young are found in spring and autumn, it is obvious that she produces twice a-year. She is careful of, and much attached to, her young; but, except in relation to these, and during the pairing season, moles lead a solitary and an isolated life. They are extremely voracious,—their appetite for food, according to Geoffroy St Hilaire, amounting to an actual phrenzy. When kept for a time in a state of abstinence they become outrageous, and will dart with violence upon whatever prey is then presented,—plunging their heads into the abdomen of birds and other animals, and satiating themselves with blood. They have been observed to refuse toads, but to seize upon frogs with avidity. With such violent propensities it may be easily conceived that they soon die of famine when debarred from food. At the same time their appetites are not so entirely carnivorous; at least several authors allege that they occasionally eat various tender and succulent roots, and the bulbs of the *colchicum*. Though deemed very injurious in gardens, and persecuted by farmers even in the open grounds, they do not want advocates who espouse their cause as useful agents in the general economy of nature; and their undoubted destruction of grubs and mole-crickets must prove beneficial to agriculture. The female, indeed, while furnishing her nursery, is a somewhat too active reaper,—402 young stalks of corn, with the leaves entire, have been counted in her nuptial chamber.

The existence of the optic nerve in moles is a greatly contested point among physiological naturalists. Durandeau and Dr Gall, conceiving vision to be impossible in the absence of that nerve, presumed it to exist in those animals in a complete and normal condition. Carus, Bailly, and Treviranus, have sought to establish its existence in a rudimentary state; while its total absence is maintained by Serres and Desmoulins. Geoffroy St Hilaire presumes himself to have reconciled these various opinions with the truth of nature, by shewing that, although the optic nerve does not occur under the same conditions as it exhibits among the normal quadrupeds, its analogue is found in a branch which proceeds from the eye to the fifth pair. Ancient writers have been accused of inaccuracy, in describing the mole as blind; and this would certainly have been a gross error in relation to an animal, of which the eyes, though small, are so distinctly perceptible. It is true that Aristotle twice repeats the assertion that the mole has no eyes; but we must remember that the true mole is extremely rare in Greece, and that the ασπαλαξ of the ancients (translated mole) is another animal (*Aspalax typhlus*), of which the eyes are in truth entirely covered by the skin. It is only in comparatively recent times that naturalists have become acquainted with a species, the remarkable conformation of which thus excuses, if it does not verify, the statement of the Stagyrite.

The only other mole found in Europe is one discovered among the Apennines by Signor Savi. It is said to be entirely blind, and has, in that belief, been named *Talpa cæca* by the Italian naturalist.[3] It is somewhat less than the common species, and one of our correspondents states his belief that it occurs in France.

Genus Centenes, Illiger. Incisives $\frac{6}{6}$ or $\frac{4}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; $= 40$ or 38.

The species of this genus resemble hedgehogs in the prickles which are intermingled with their hair, but their teeth are very different. They are nocturnal animals, and inhabitants of the torrid zone (occurring in Madagascar and the Isle of France), and are said to pass several months of the year in a lethargic state. This is a singular circumstance in the history of any intertropical species; and the term hybernation, usually bestowed upon the torpid condition (in consequence of its constant connection with the cold of winter), cannot be used in the present instance, because, according to the relation of Bruguiere, it most frequently occurs during the greatest heats. About three species of the genus are known to naturalists. As an example, we have figured the radiated Tanrec (*Centenes semi-spinosus*), which is no larger than a mole (See Plate III., figure 10.) The tanrecs are known to Europeans under the title of pig-porcupines. They utter a grunting cry, are generally very fat, and are used as food by the natives of Madagascar.

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[1] The student who finds a discrepancy in our statement of the above dentition (or in that of other insectivorous groups), when compared with the descriptions of other authors, will bear in mind that this arises chiefly from a difference in nomenclature. In the present instance we follow M. Desmarest. Baron Cuvier seems to think that in *Condylura* there are only two pair of incisive teeth in the upper jaw; what we have considered as the third pair, being regarded by him as the canines. We presume the place of their insertion in relation to the maxillary bone would determine the point; but we have ourselves no access to a cranium of any species of the genus.

[2] Bartram and other writers who have asserted the existence of moles in America, are supposed by later writers to have mistaken the shrew-mole (*scalops*). Sir J. Richardson, however, informs us that there are several true moles in the Museum of the Zoological Society, which were brought from America. They differ from the common European species in being smaller in size, with a thicker and shorter snout. The fur is brownish-black. Dr Harlan supposes the mole of the United States synonymous with *T. europæa* of Linn. It was named *T. americana* in Dr Bartram's MS.

[3] *Memoire Scientifiche, decade prima.* Consult also C. L. Bonaparte's *Iconografia della Fauna Italica.*

DIVISION III.—CARNIVORA.

The genera of this division are characterized by possessing six incisors in each jaw. Their molars are usually of a trenchant or cutting character, sometimes tuberculous, but never beset with the jagged points which we so often meet with in the preceding division. Their canines are extremely strong.

Although the epithet carnivorous, as Baron Cuvier has remarked, applies, in a considerable degree, to all unguiculated quadrupeds which possess the three different kinds of teeth, since the whole are more or less dependent on animal matter for their support, yet it is among the various groups of our present division that we meet with the really sanguinary kinds. They are more or less exclusively carnivorous, according as their teeth are more or less of a cutting character, and their regimen might almost be calculated from the relative proportion between the tubercular and the cutting surface of their grinders. The bear tribe, which is the best adapted (of carnivorous creatures) for subsisting on a vegetable diet, has almost all the teeth tubercular. Hence the accordance of its love for fruits and berries.

The anterior molars of this division are usually the sharpest on their edges; then follows a molar larger than the others, and usually furnished with a tubercular heel. Behind that molar we find one or two small teeth nearly flat upon the crown. It is with these latter that dogs chew the grass which they so frequently swallow. The great molar just alluded to, and the corresponding tooth of the upper jaw, are what we designate as the carnivorous cheek-teeth (*les carnassieres* of F. Cuvier); the anterior pointed ones are the false molars, and the flattened posterior ones, the tubercular grinders. The amount of these teeth differs slightly in some of the genera. Thus, for example, in the feline race, or cats, there is no separate tubercular tooth in the lower jaw; but its function is performed by the inner projecting lobe of the under carnivorous cheek-tooth, the rounded point of which, when the jaws are closed, is applied to the flat surface of the upper tubercular grinder. It will be readily conceived that such species as possess the fewest false molars, and the shortest jaws, have the greatest power in biting, and are likely to prove the most carnivorous.

We subdivide the CARNIVORA, in the first place, into three principal tribes, in accordance chiefly with certain distinctive peculiarities in the form of the hinder feet. These tribes are named PLANTIGRADA, DIGITIGRADA, and PINNIPEDIA.

TRIBE I.—PLANTIGRADA.

Entire sole of the foot placed upon the ground in walking. Five toes to both the fore and hind extremities. No cæcum.

GENUS URSUS. Linn. Incisors $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molar $\frac{6-6}{7-7}$; $=42$. Tail short.

Of the six molars on each side of the upper jaw of this genus there are three which we would denominate false molars; another corresponds to the carnivorous cheek-tooth, and the remaining two are tuberculated grinders. In the under jaw there is generally an additional molar on each side. It must be remembered, however, that the number of teeth in the bears is very variable even in the same species, according to the age of the individual. The false molars especially vary greatly,—for in young animals they have not become apparent,—in aged ones they have disappeared.

Among carnivorous quadrupeds, as we have already hinted, we find many different degrees of ferocity, from the all-subduing and blood-thirsty disposition of the tiger, which so savagely rejoices to imbrue its horrid jaws in the palpitating flesh of a living victim, to the more omnivorous propensities of the Plantigrada, such as the bear, racoon, or coati-mundi,—species which, though addicted to prey on other animals, are at the same time endowed with a much greater capacity to adapt their constitution to a miscellaneous diet. This accommodating instinct no doubt corresponds with, if it does not proceed from, the less determinate formation of the digestive and prehensile organs; such as the stomach, teeth, and claws. The unequalled strength and activity of the tiger,—its sharp retractile talons, the great development of the canine teeth, and the compressed and cutting character of the molars, combined with the simplicity of the stomach, and the shortness of the intestinal canal, render it, as it were, the type of carnivorous animals. It exhibits no tendency in any of its forms to the herbivorous structure, but is strictly and characteristically a flesh-eating animal, "a most beautiful and cruel beast of prey." It is otherwise with our present genus, containing the race of bears. Their external forms are massy and inactive, their claws are unretractile, their muzzles more elongated, their jaws consequently weaker, and their teeth, though sufficiently formidable, manifest a decided relation to the herbivorous structure in the breadth of the molars, and their bluntly tuberculated crowns. In accordance with these conditions of their organization, we find that even the polar bear (*Ursus maritimus*), one of the most carnivorous of its kind, may be sustained for a length of time in captivity, on bread alone. It is known that several species, in the wild state, are remarkably fond of honey (a substance which, though in one sense an animal secretion, is, in another and more essential one, a vegetable product), and have been observed climbing trees to obtain it. Others feed on fruits, reptiles, insects, particularly ants; and Sir Stamford Raffles possessed a tame Malay bear (*U. Malayanus*), which gave proof of its refined appetite, by refusing to eat any thing but mangosteens, or to drink any other wine than champagne.[1]

Here, then, as among every other group which can occupy the attention of the naturalist, we find the most beautiful and harmonious uniformity to prevail between the special end in view, and the means of its attainment. Of all carnivorous animals, bears are the least qualified either to pursue in open warfare, or to secure by ambuscade, a living prey. Their plantigrade position renders their movements comparatively slow, and the nearly equal length of their fore and hind legs deprives them of the power of leaping. Had, therefore, their natural love of flesh and blood been as insatiable as that of the tiger, and their means of obtaining it so much more restricted, their lives must have passed in misery, and the species would ere long have become extinct.[2] But HE who "tempers the wind to the shorn lamb," has drawn strength from this very weakness, and ordained that, with the deterioration of those characters which are essential to the well-being of a strictly carnivorous animal, should arise a capacity of deriving nourishment from a wider and more miscellaneous range of materials,—and thus the balance is beautifully maintained between the instinctive propensity and the subduing power.

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[1] *Linn. Trans.* vol. xii.

[2] Wilson's *Illustrations of Zoology*, vol. i. Genus Ursus.

The geographical distribution of the genus *Ursus*, though formerly believed to be confined to northern countries, is now known to be very extensive. We are acquainted with eight or nine species, several of which occur in the warmer regions of Continental Asia, and the Indian Islands. We cannot here, however, afford room for more than the briefest summary. The white or polar bear (*U. maritimus*), which does not occur among the antarctic icebergs, is common to the northern shores of Asia and America. This gigantic prowler among frost-bound regions, attains to a higher latitude than any other known quadruped, and seems indeed to dwell by preference

> "In thrilling regions of thick-ribbed ice."

Its southern limit seems to be somewhere about the 55th parallel. It is a truly ice-haunting and maritime species, occurring along a vast extent of shore, but never entering into wooded countries, except by inadvertence, or during the prevalence of great mists, nor shewing itself, unless accidentally, at any considerable distance from the sea.[1]

It might naturally be supposed, that animals of almost gigantic size, of great strength, and considerable ferocity, would be too formidable and dangerous to the human race, to remain long unknown in any of their distinguishing characteristics. Yet the specific differences, it must be admitted, of the black and brown bears, both of Europe and America, are still insufficiently illustrated. Both continents produce a black bear and a brown one; the white or polar species, just mentioned, is common to the northern latitudes of each, while America alone is inhabited by the grizzly bear, *Ursus ferox*. This is undoubtedly the most formidable animal of the northern parts of the New World. When full grown it equals in size the great polar species, and is not only of more active habits, but of a fiercer and more vindictive disposition. Its strength is so enormous, that it will drag away the carcass of a buffalo weighing a thousand pounds. Dr Richardson informs us, that a party of voyagers, who had been occupied all day in tracking a canoe up the Saskatchewan, were seated around a fire enjoying the repose of the evening twilight, and partly occupied in the agreeable task of preparing their supper. Suddenly a huge grizzly bear sprung over the canoe, which they had tilted behind them, and seizing one of the party by the shoulder, carried him off. The remainder were scattered in terror, with the sole exception of a *metif* named Bourasso, who, grasping his gun, followed the bear, whom he saw deliberately retreating with his companion in his mouth. He called out to his unfortunate comrade that he was afraid to fire lest he should hit him instead of the bear, but he was answered to fire instantly, as the monster was *squeezing him to death*. On this he took steady aim, and lodged his ball in the body of the brute, which immediately dropped its original prey, and turned round to revenge itself upon the brave Bourasso. He, however, contrived to effect his escape, and the bear, probably feeling itself severely wounded, disappeared into a neighbouring thicket. The rescued man eventually recovered, although one of his arms was fractured, and he was otherwise severely bitten. Another individual, still living in the neighbourhood of Edmonton House, was attacked by a bear of this species, which suddenly sprung out of a thicket, and *scalped* him by a single scratch of its tremendous claws, laying bare the skull, and pulling down the skin of the forehead quite over the eyes. Assistance being at hand, he was rescued from the bear without farther injury, but he was left in a painful and unfortunate predicament, for the scalp not being properly replaced in time, he lost the power of vision (although his eyes remained uninjured), owing to the hardening of that skinny and tenacious veil.[2] The grizzly bear inhabits the Rocky Mountains, and their eastern plains, at least as far north as latitude 61°, and its southern range, according to Lieutenant Pike, extends to Mexico.[3]

Another and much smaller species of the New World is the black bear of North America (*U. Americanus*, see Plate IV., figure 3). It is esteemed as food. The only South American species with which we are acquainted, is the *Ursus ornatus* of Frederick Cuvier (*Ibid.* figs. 4 and 4 *a*). It is black, with the throat and muzzle white, and a large fulvous spot upon the brows. The European bears are generally supposed to be two in number, the brown or common bear (*U. arctos*, Linn.), and the black bear (*U. niger*). The latter, however, is by some considered only as a variety. There are at least three bears in India. The long-lipped bear (*U. labiatus*) is met with occasionally in menageries in this country, under the name of Ursine Sloth (first bestowed upon an individual accidentally deficient in the canine teeth). It dwells in holes and caverns, which it sometimes excavates with its long claws, and feeds on fruit, insects, and honey. It is rather a docile and intelligent animal, and is taught various tricks by the jugglers of Bengal, who frequently exhibit it for the amusement of the people. The Malay bear (*U. Malayanus*, Raffles), before alluded to, occurs likewise in Sumatra, where it is said to cause great damage by climbing to the summit of the cocoa trees to drink the milk, after devouring the tops of the plant. A third Indian species is the bear of Thibet (*U. Tibetanus*, Cuv.), a species intermediate between the two preceding, but more ferocious than either. Its claws are weaker than usual, and some suppose that it cannot climb trees. It was found by Dr Wallich among the mountains of Nepaul, and by M. A. Duvaucel in those of Silhet. We may conclude by observing, that bears have never been found in any part of Africa in modern times, although those of Lybia are mentioned by Virgil and other ancients:—

> Acestes
> Horridus in jaculis et pelle Libystidis ursæ.

GENUS PROCYON, Storr., Cuv. Incisors $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molar $\frac{6-6}{6-6}$; $=40$. Tail long. Six ventral mammæ.

This genus contains the animals commonly called racoons. We have no precise knowledge of more than two species. The first is the common racoon of North America (*P. lotor*, Cuv. *Ursus lotor*, Linn.), a fox-like creature, with the gait of a bear. In a state of nature it sleeps throughout the day, prowling during the night in search of fruits, roots, birds, eggs, and insects. At low water it frequents the sea-shore, where it preys on crustacea and shell-fish. It climbs trees with great facility. According to M. Desmarest it extends as far south as Paraguay. But it is the second species or crab-eating racoon (*P. cancrivorus*, Geoff.), which is the more characteristic of the southern portion of the New World.

The genus AILURUS of Fred. Cuvier, may be here mentioned as allied to the racoons. It possesses, however, only one false molar instead of three. Its dentition is not distinctly known. One species only has been hitherto recognised, the *A. fulgens*, a native of the mountains of Northern India.[1] It is an extremely beautiful animal, clothed in a soft dense fur, the upper parts of a bright cinnamon red, the under surface deep black. In size it resembles a large domestic cat, and dwells by preference among trees in the vicinity of streams and torrents, preying on birds and small quadrupeds. It offers in some measure a combination of the characters of the bears, civets, and racoons. (See Plate IV., figures 6 and 6 *a*.)

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[1] The student who desires to complete his knowledge of this interesting animal, is referred to Martin's *Voyage to Spitzbergen*, Fabricius's *Fauna Grœnlandica*, Pennant's *Arctic Zoology*, Scoresby's *Account of the Arctic Regions*, the *Appendix* to Parry's *Second Voyage*, and Richardson's *Fauna Boreali-Americana*, part 1st. The same works may of course be consulted with equal advantage for the history and description of other arctic quadrupeds.

[2] *Fauna Boreali-Americana*, part 1st, p. 27.

[3] *Travels on the Missouri and Arkansaw.*

Another recently constructed genus is named ICTIDES, by M. Valenciennes.[2] The three hindermost molars of the upper jaw are much smaller and less tuberculated than those of the racoons, especially the farthest back in each jaw, which is very small and almost simple. (See Plate IV., figure 5.) The tail is long and densely furred, with an involved appearance as if it were prehensile. Two species have been described,—*Ict. albifrons*, a native of Sumatra, Malacca, and Java; and *Ict. ater*, found chiefly in Malacca. They are not yet distinctly characterized or discriminated, and one or other of them is the *Binturong* of Raffles.[3] It was observed to climb trees, with the assistance of its tail, which has uncommon strength. Major Farquhar kept one alive for many years. It fed both on animal and vegetable food, was particularly fond of plantains, but also ate readily of fowl's heads, eggs, &c. It was most active during the night.[4]

GENUS NASUA, Storr., Cuv. Incisors $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; = 40. Tail long, covered with hair, not prehensile. Six ventral mammæ. No cæcum.

This genus contains the well-known South American animals called *coatis*, or *coati mondis*, so frequently seen in our menageries. Individuals vary greatly in colour, and it is the impression of some observers, that the red and brown coatis, *N. rufa* and *fusca* (*Viverra nasua* and *nasica* of Linn.), are identical. We have represented the so called *Nasua rufa* on Plate IV., figure 7. In a state of nature these animals dwell in the woods, preying on such small birds and quadrupeds as they can overcome, and producing occasional devastation in sugar-cane plantations. They are often domesticated in Brazil, Guiana, and Paraguay, but it is necessary to keep them chained, as they climb better than cats, and are always getting into mischief, from their restless activity and habits (otherwise praiseworthy) of general inquiry, which induce them to poke their snouts into every unaccustomed hole and corner. A specimen at present in our possession is extremely domestic, much attached to society, and also very fond of strawberries, earthworms, honey, eggs, chickens (either raw or roasted), young frogs, and green pease.

We may here allude briefly to the genus POTOS of Geoffroy (*Cercoleptes*, Illiger), which contains only a single species of a somewhat anomalous aspect. It is the *yellow maucoco* of Pennant (*P. caudivolvulus*, Desm.), frequently called the *kinkajou*. Its size is nearly that of a domestic cat, and its physiognomy is remarkably like a lemur's. A tame one kept by F. Cuvier was mild and fond of caresses. It loved obscurity, and slept much during the day. It occasionally ate meat, but preferred a vegetable diet. It was a dexterous climber. According to Humboldt it is very abundant in New Grenada, and was among the number of those animals formerly reduced by the aborigines to a domestic state. It is said to be a great destroyer of the nests of wild bees, and makes use of its long tongue to extract their gathered sweets. On this account it was named the *honey bear*, by the missionaries.

GENUS MELES, Storr. Incisives $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molars $\frac{5-5}{6-6}$; = 38. Tail very short. Two pectoral and four ventral mammæ. An anal pouch.

Here naturalists place the badgers, a small genus, widely distributed over Europe, and occurring both in Asia and America. At the same time we have no precise knowledge of more than two species. Our common badger (*Meles vulgaris, Ursus meles*, Linn.) is greyish-brown above, beneath black, with a longitudinal black band on each side of the head, passing round the eye and ear. The tuberculous molars at the bottom of each jaw, especially those of the upper, are distinguished by their extent, of which the effect is to limit that of the carnivorous teeth, and consequently to diminish the natural appetite for flesh, or, at all events, the power of exercising it. The tuberculous molar of the upper jaw, occupies a space equal to that of the carnivorous cheek tooth, and of the two false molars, by which it is preceded, and the lower half of the under carnivorous tooth is enlarged, so as to be properly opposed to the larger tuberculous tooth above. It is thus half tuberculous and half carnivorous. The second incisives of each side of the lower jaw are not inserted on the same line as the others, but farther in. Although the badger is undoubtedly a carnivorous animal, it is much less so than many others of the ferine order, and even in a state of nature feeds freely on fruits and roots. We have known it enter a garden to devour strawberries. When domesticated it is omnivorous, like the cat and dog. Its subterranean life, and woodland habits, are well known.

The American badger (*Meles Labradoria* of Richardson and others), or *carcajou* of Buffon, is of a mottled or hoary grey colour above, whitish on the under surface. The fur is very soft and fine. This species inhabits the sandy plains or prairies which skirt the Rocky Mountains as far north as the banks of the Peace River. It abounds in the plains of the Missouri, although its southern range has not been hitherto defined. The holes which it perforates in the prairies, in the vicinity of Carlton-house, are often annoying to horsemen, especially when the ground is covered with snow. The greater number of these burrows, however, are not dug by the badger itself, but are merely enlargements of the subterranean dwellings of marmots (*Arctomys Hoodii* and *Richardsonii*), which it at the same time most ungenerously digs up and devours. It appears indeed to be fully more carnivorous than the European species,—a specimen which Sir J. Richardson killed, having had a small marmot nearly entire, and several field mice, in its interior. But it had also been feeding on some vegetable matter. It passes the winter, from November to April, in a torpid state.[5]

Although the badgers approach the marten tribe in the characters of their dentition, they are far from resembling those finely formed, light, and lively creatures in other particulars; their bodies, though strong and muscular, being rather heavily formed, and their movements by no means active. Their physiognomy, it has been observed, announces neither quickness of intelligence, nor vivacity of passion. They lead a retired, if not a solitary life. Badgers, though frequently mentioned by Latin writers under the names of *taxus* and *meles*, seem to have passed unnoticed by the Greeks. Yet we know that the European species occurs in Calabria.

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[1] See *Linn. Trans.* vol. xv. p. 161.

[2] *Annales des Sciences Nat.* t. iv.

[3] The species have even been commingled by several recent systematic writers with the genus *Paradoxurus*.

[4] *Linn. Trans.* vol. xiii. p. 254.

[5] *Fauna Boreali-Americana*, Part i. p. 39.

GENUS GULO. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{6-6}$, or $\frac{4-4}{6-6}$; $=$ 38 or 36. No anal pouch.

The Glutton of the north of Europe (*Gulo arcticus*, *Ursus gulo*, Linn.) may be mentioned as an example of our present genus. It is common in Norway, especially in the neighbourhood of Drontheim, and is remarkable for its fierceness and voracity. It is said to climb trees, that it may the more readily pounce upon deer and other large animals which it could not otherwise obtain. It fastens on their necks with teeth and claws, till its astounded prey rolls upon the earth from loss of blood, or terror at such an unexpected and insidious foe. In a domestic state it has been known to eat thirteen pounds of flesh in a single day. It is not larger than a badger. The glutton does not become torpid in the winter season.

The Wolverine of North America (*Gulo luseus*, Sabine), though regarded by Baron Cuvier as nothing more than a variety of the preceding, is by others considered as a well distinguished species. Its habits are characteristically described by Sir J. Richardson: "The Wolverine is a carnivorous animal, which feeds chiefly upon the carcasses of beasts that have been killed by accident. It has great strength, and annoys the natives by destroying their hoards of provision, and demolishing their marten traps. It is so suspicious, that it will rarely enter a trap itself, but, beginning behind, pulls it to pieces, scatters the logs of which it is built, and then carries off the bait. It feeds also on meadow-mice, marmots, and other *rodentia*, and occasionally on disabled quadrupeds of a larger size. I have seen one chasing an American hare, which was at the same time harassed by a snowy owl. It resembles the bear in its gait, and is not fleet; but it is very industrious, and no doubt feeds well, as it is generally fat. It is much abroad in the winter, and the track of its journey in a single night may be often traced for many miles. From the shortness of its legs, its makes its way through loose snow with difficulty, but when it falls upon the beaten track of a marten trapper, it will pursue it for a long way. Mr Graham observes, 'that the Wolverines are extremely mischievous, and do more damage to the small fur trade, than all the other rapacious animals conjointly. They will follow the marten hunter's path round a line of traps extending forty, fifty, or sixty miles, and render the whole unserviceable, merely to come at the baits, which are generally the head of a partridge, or a bit of dried venison. They are not fond of the martens themselves, but never fail of tearing them in pieces, or of burying them in the snow by the side of the path, at a considerable distance from the trap. Drifts of snow often conceal the repositories thus made of the martens from the hunter, in which case they furnish a regale to the hungry fox, whose sagacious nostril guides him unerringly to the spot. Two or three foxes are often seen following a wolverine for this purpose.'[1] The wolverine is said to be a great destroyer of beavers, but it must be only in the summer, when those industrious animals are at work on land, that it can surprise them. An attempt to break open their house in the winter, even supposing it possible for the claws of a wolverine to penetrate the thick mud walls when frozen as hard as stone, would only have the effect of driving the beavers into the water to seek for shelter in their vaults on the borders of the dam."[2] Next to the polar bear, the wolverine is one of the most northern of known quadrupeds. Its bones were found in Melville Island, nearly in latitude 75°.

A third species of this genus is the Grison, or banded glutton (*G. vittatus*), an inhabitant of a warmer clime. It is very common in Paraguay. A fourth is the Taira (*G. barbatus*,—*Mustelus barbatus*, Linn.), described by Azara under the name of *le grand furet*. It is likewise a native of South America.

The *Ratel*, or cape glutton (*G. mellivorus*,—*Viverra mellivora* and *capensis*, Gmelin), differs from the preceding in having one false molar less in each jaw, and in the upper tubercular teeth being slightly developed, as in cats; but in its external aspect it resembles the grison and badger. It is described by Sparmann as being about the size of the latter,—the fur greyish above, and black below, with an intermediate line of white. It inhabits the Cape of Good Hope, where, with its long claws, it disinters the nests of wild bees, and feeds upon their honey. Though long regarded as exclusively of African origin, it now appears, on the testimony of General Hardwick, to occur in several parts of India, along the courses of the Ganges and the Jumna. Its manners, however, do not at all correspond with those assigned to the African variety. It inhabits the high banks of the great rivers, and seldom issues abroad during the day. At night it prowls about the Mahommedan habitations, and will sometimes even scratch up recently interred human bodies, unless the graves be protected by a covering of thorny shrubs. So rapid indeed are its subterranean operations, that it will work its way beneath the surface in the course of ten minutes. Its favourite food consists of birds and small quadrupeds. There is a specimen of this animal in the London Zoological Gardens, remarkable for its playfulness and good humour. It solicits attention by a great variety of postures, and tumbles head over heels as soon as it has succeeded in attracting the notice of a visitor.[3]

TRIBE II.—DIGITIGRADA.

The groups of this tribe derive their name from their peculiar mode of locomotion. The heel does not touch the ground, and the act of walking is performed, as it were, upon the toes. We may name as familiar examples the pole-cats, martens, dogs, hyenas, and the whole of the feline race. Like most of our attempts, however, at a general arrangement, founded on any single attribute, we find this principle imperfect, or at least admitting of exceptions in relation to the character prescribed, in as far as several species might be adduced, which truly agree with their digitigrade congeners in their prevailing character, but approach the plantigrades in their mode of locomotion.

The genuine *Digitigrades*, however, such as cats, are among the most agile of their tribe, and as activity is an almost indispensable adjunct in the habits of a carnivorous creature, we find that these light-footed kinds are also the most exclusively flesh-eating of all the ferine order. Indeed all the genera of our present tribe may be said to be more strictly carnivorous than those of the preceding.

1ST SUBDIVISION.

A single tuberculous tooth behind the carnivorous cheek-tooth of the upper jaw. Body much elongated. Limbs short.

This subdivision corresponds to the old genus MUSTELA of Linnæus, and includes all those small and slender bodied animals which, in our own country, are usually designated as *vermin*, such as weasels, polecats, &c., the *Verminium genus* of Ray. They are very blood-thirsty, and extremely destructive for their size, destroying great quantities of game, both in woods, fields, and moorish mountains, and committing ravages in poultry-yards, and other enclosures, especially of remote country dwellings. They are wary, nocturnal, and insidious, and, from their worm-like form, can penetrate minute openings,—thus gaining access to places where their presence was little expected, and less desired. The general dentition may be stated as: incisives $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molars $\frac{4-4}{5-5}$ or $\frac{5-5}{6-6}$; = 34 or 38.

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[1] Graham's *MSS.* p. 13.

[2] *Fauna Boreali-Americana*, Part i. p. 43.

[3] *Gardens and Menagerie*, vol. i. p. 20.

We shall now proceed to give a short sketch of the minor genera (increased in number though restricted in extent), into which the musteline group of Linnæus has been subdivided in recent times.

The polecats (subgenus *Putorius*, Cuv.[1]) are among the most sanguinary. Their lower carnivorous cheek-tooth has no interior tubercle, their upper tubercular tooth is broader than long, and they have only two false molars above and three below, on each side. They exhale a strong and disagreeable odour. The species are extremely numerous, and widely spread. We have three well known British kinds,—the foumart, or common polecat (*M. putorius*, Linn.), of which the ferret (*M. furo*) is regarded simply as a variety by some,—the weasel (*M. vulgaris*, Linn.), and the ermine or stoat (*M. erminea*, Linn.). Another species, remarkable for its amphibious habits, and known under the name of *Mink* (*Mustela lutreola*, Pallas), is very common in Finland, and in other parts of the north and east of Europe, from the Icy to the Black Sea. Erxleben, however, is in error when he supposes it to be a North American species. The animal of the New World is the vison (*M. vison*, Gmelin) or minx otter of Pennant.[2] Both species prey much on fish, reptiles, and aquatic insects, and the latter is easily tamed. "One," says Sir J. Richardson, "which I saw in the possession of a Canadian woman, passed the day in her pocket, looking out occasionally, when its attention was roused by any unusual noise."[3] Other species inhabit the warmer countries of the earth, such as Africa (*P. africanus*, Desm.), Madagascar (*P. striatus*, F. Cuvier), and Java (*P. nudipes*, Id.). The last-named animal, of a yellowish fawn-colour, with the head and termination of the tail white, is figured in this work, Plate V., figure 1. There is a Cape species (*Viverra zorilla*, Gmelin) which, in its general aspect, resembles the polecats; yet the form of its fore-claws is somewhat peculiar, and seems to indicate subterranean habits of life, and a propensity to dig. It has, on this account, been formed by some authors into a separate subgenus under the name of *Zorilla*,—perhaps an inappropriate title, and apt to mislead the student, in as far as it was first applied by Spanish writers to one of the mephitic species of America.

The Martens properly so called (MUSTELA of Cuvier, but to which the generic name of MARTES would be more appropriately applied), have a small interior tubercle on the lower carnivorous cheek-tooth, and (compared with the preceding) an additional false molar both above and below. Each of these characters is supposed to indicate some diminution of the purely carnivorous propensity. We have two British species, the common or beech marten (*M. fagorum*, Ray, *M. martes*, var. *fagorum*, Linn.), of which the throat and breast are white, and the pine marten (*M. abietum*, Ray, *M. martes*, var. *abietum*, Linn.), of which the throat and breast are dingy yellow. The former is the more common in England, and the southern and central parts of Scotland,—the latter prevails in the north. Though the specific names are derived from their supposed propensities towards particular kinds of forests, it appears that their habits, like those of most other species, are of an accommodating kind. Both sorts, and more especially the first named, are often found in districts "rocky, bare, sublime," of which the most hopeless attribute is that of forest scenery. The common marten more frequently approaches farm-houses than the other, and was probably, for that reason, distinguished by the name of *domestica* by the old writers, such as Gesner and Aldrovandus. The pine marten is extremely common over the northern parts of America, from the Atlantic to the Pacific, and is particularly abundant where the trees have remained standing after being killed by fire. Its fur is fine, and has long formed an important article of commerce, upwards of a hundred thousand skins being collected annually in the districts devoted to the trade. It is well known that it also formed a lucrative subject of export from Scotland before the Union. Dr Fleming says it builds its nest on the tops of trees. According to Sir J. Richardson, its habits in America are rather subterraneous. We have seen its young winding their worm-like way amid the treeless *corries* of the Highland mountains, where not even a sapling wild-ash waved its leaves in the grey solitude.

One of the most famous of the foreign martens is the zibelline or sable (*M. Zibellina*, Linn.), so noted for the beauty of its fur. It is very like our martens both in size and proportions, and is usually of a rich lustrous brown colour, somewhat paler in summer, and marked during that season with grey upon the throat, and whitish on the ears and face. It is spread over a wide extent of northern Asia, where it is held in the highest estimation of all the fur-bearing animals; and its pursuit among the frozen wastes of Siberia and Kamtschatka is probably the most painful as well as perilous of those sacrifices which the human race, either by force or free will, have ever made to the love of riches. The winter robe is by much the most esteemed, being then fuller, darker, softer, and more flexible and lustrous than at any other season. In this state it is equally coveted by Chinese mandarins, Tartarian chiefs, and the noblesse of Europe, and is justly regarded as one of the most precious and magnificent of all the artificial adornments of the human frame. A single skin of the richest quality is worth from twelve to fourteen pounds, and in its attempted acquisition many hardy hunters perish miserably of cold and famine. The Russian dealers, however, are so skilful in the perfect preparation of these furs, that they often succeed in selling the summer skins for those of winter. We may add, that to the pursuit of the sable we owe the discovery of the eastern countries of Siberia.

The pekan or fisher (*M. canadensis*, Linn.) is a well known species of North America. Its habits resemble those of the pine marten, but it is nearly twice the size, and its fur is coarser, and less valuable.

GENUS MEPHITIS, Cuv. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{4-4}{5-5}$; = 34. As in the polecats, there are two false molars above and three below, but the upper tubercular tooth is very large, and as long as broad; the lower carnivorous cheek tooth has two tubercles on its inner side, a character in which the species approach the badgers. They resemble the latter also in the lengthened claws of the fore feet, and the almost plantigrade form of the hinder extremities.

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[1] Baron Cuvier has applied the generic name *Putorius* to the group which contains the polecat and the weasel, and he bestows that of *Mustela* on the martens. We think the latter should have been given to whatever group contained the true weasel (*M. vulgaris*, Linn). as it is otherwise apt to carry false associations. Some recent writers adopt the genus *Putorius*, as assigned by Cuvier, but give the title of *Martes* to the martens properly so called. This is very well in its way, but then we lose the term *mustela* altogether as a generic appellation. Now we think, that whenever a Linnæan genus is raised to the rank of a family, the original generic title should still be retained, as indicative of one of the restricted groups.

[2] *Arctic Zoology*, vol. i. p. 87, and *Fauna Boreali-Americana*, Part i. p. 48.

[3] *Ibid.* p. 49.

The animals of this genus are commonly called skunks or mephitic weasels, and are remarkable for their intense and ineradicable odour. Although several species are described by naturalists, it does not clearly appear that more exists than one, the skunk weasel of Pennant (*Mephitis Americana*, Rich., *Viverra putorius*, Gmelin), which is spread over a great extent of territory in the New World, and varies in different localities. Its size is that of a domestic cat, its fur, though rather coarse, is very ample, of a black colour, marked by longitudinal bands of white, and the tail, which is long and bushy, has generally two broad longitudinal white stripes above upon a black ground. The skunk, as described by Sir J. Richardson, inhabits rocky and woody regions, spending the winter in a hole, and seldom stirring abroad during the colder seasons. It preys on mice, and in summer feeds much on frogs. Its gait is slow, and it can be easily overtaken by its pursuers, as it makes no great efforts to escape by flight, but trusts the discomfiture of its enemies to the discharge of a most noisome fluid. This fluid, which is of a deep yellow colour, is contained in a small bag placed at the root of the tail, and emits probably the most overpowering stench in the known world. It is so durable, that wherever a skunk has been killed, the place retains a taint for many days. "Mr Graham says that he knew several Indians who had lost their eyesight in consequence of inflammation, produced by this fluid having been thrown into them by the animal, which has the power of ejecting it to the distance of upwards of four feet. I have known," adds Sir J. Richardson, "a dead skunk thrown over the stockades of a trading post produce instant nausea in several women in a house with closed doors upwards of a hundred yards distant. The odour has some resemblance to that of garlic, although much more disagreeable. One may, however, soon become familiarized with it; for, notwithstanding the disgust it produces at first, I have managed to skin a couple of recent specimens by recurring to the task at intervals. When care is taken not to soil the carcass with any of the strong smelling fluid, the meat is considered by the natives to be excellent food. It breeds once a-year, and has from six to ten young at a time."[1] Not fewer than fifteen varieties of this animal have been described, and many of them under separate names, as distinct species. It is singular that the Hudson's Bay variety should approach most nearly to the description of the *Chinche* of Buffon (*Viverra mephitis*, Gmelin), which, though said to be an inhabitant of Chili, is yet regarded by some observers as identical with the skunk of more northern regions, and to the same or closely related species we may also no doubt refer the so-called glutton of Quito (*Gulo Quitensis*), described by Humboldt.[2]

GENUS MYDAUS, Horsfield. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{4-4}{5-5}$; = 34. Muzzle truncated, or pig like. Tail very short.

The only known species of this genus is the *Teledu* of Java (*M. meliceps*, Horsfield), classed as a *Mephitis* by Desmarest and others. In its dentition it certainly agrees closely with the mephitic weasels of America, but its external character and physiognomy are peculiar, its form being heavy, its neck strong and short, and its mode of progression almost entirely plantigrade. It emits an odour very similar to that of the skunk. "The *Mydaus meliceps*," says Dr Horsfield, in his excellent account of this curious animal, "presents a singular fact in its geographical distribution. It is confined exclusively to those mountains which have an elevation of more than 7000 feet above the level of the ocean; on these it occurs with as much regularity as many plants. The long extended surface of Java, abounding with conical points which exceed this elevation, affords many places favourable for its resort. On ascending these mountains, the traveller scarcely fails to meet with our animal, which, from its peculiarities, is universally known to the inhabitants of these elevated tracts; while to those of the plains it is as strange as an animal from a foreign country. A traveller would inquire in vain for the Teledu at Batavia, Semarang, or Surabaya. In my visits to the mountainous districts I uniformly met with it; and, as far as the information of the natives can be relied on, it is found on all the mountains. It is, however, more abundant on those which, after reaching a certain elevation, consist of numerous connected horizontal ridges, than on those which terminate in a defined conical peak. Of the former description are the mountain Prahu and the Tengger Hills, which are both distinctly indicated in Sir Stamford Raffles' map of Java: here I observed it in great abundance. It was the less common on mountain Gede, south of Batavia; on the mountain Ungarang, south of Semarang; and on the mountain Ijen, at the farthest eastern extremity; but I traced its range through the whole island.

"Most of these mountains and ridges furnish tracts of considerable extent, fitted for the cultivation of wheat and other European grains. Certain extra-tropical fruits are likewise raised with success. Peaches and strawberries grow in considerable abundance, and the common culinary vegetables of Europe are cultivated to great extent. To most Europeans and Chinese a residence in these elevated regions is extremely desirable; and even the natives, who in general dislike its cold atmosphere, are attracted by the fertility of the soil, and find it an advantage to establish villages, and to clear grounds for culture. Potatoes, cabbages, and many other culinary vegetables are extensively raised, as the entire supply of the plains in these articles depends on these elevated districts. Extensive plantations of wheat and of other European grains, as well as of tobacco, are here found, where rice, the universal product of the plains, refuses to grow. These grounds and plantations are laid out in the deep vegetable mould, where the teledu holds its range as the most ancient inhabitant of the soil. In its rambles in search of food, this animal frequently enters the plantations and destroys the roots of young plants; in this manner it causes extensive injury, and on the Tengger Hills particularly, where these plantations are more extensive than in other elevated tracts, its visits are much dreaded by the inhabitants; it burrows in the earth with its nose, in the same manner as hogs; and, in traversing the hills, its nocturnal toils are observed in the morning, in small ridges of mould recently turned up.

"The Mydaus forms its dwelling at a slight depth beneath the surface, in the black mould, with considerable ingenuity. Having selected a spot, defended above by the roots of a large tree, it constructs a cell or chamber of a globular form, having a diameter of several feet, the sides of which it makes perfectly smooth and regular; this it provides with a subterraneous conduit or avenue, about six feet in length, the external entrance to which it conceals with twigs and dry leaves. During the day it remains concealed like a badger in its hole; at night it proceeds in search of its food, which consists of insects and their larvæ, and of worms of every kind; it is particularly fond of the common lumbrici, or earthworms, which abound in the fertile mould. These animals, agreeably to the information of the natives, live in pairs, and the female produces two or three young at a birth.

"The motions of the mydaus are slow, and it is easily taken by the natives, who by no means fear it. During my abode on the mountain Prahu, I engaged them to procure me individuals for preparation; and as they received a desirable reward, they brought them to me daily in greater numbers than I could employ. Whenever the natives surprise them suddenly, they prepare them for food; the flesh is then scarcely impregnated with the offensive odour, and is described as very delicious. The animals are generally in excellent condition, as their food abounds in fertile mould."[1]

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[1] *Fauna Boreali-Americana*, p. i. p. 55.

[2] *Recueil d'Observations sur la Zoologie.*

We may add, that the teledu is by no means ferocious in its manners, and, if taken young, might no doubt be easily domesticated. An individual, retained for some time in confinement by Dr Horsfield, afforded him an opportunity of studying its disposition. It soon became gentle and reconciled to its situation, and never emitted its offensive effluvium. In the natural state, however, its odour is so strong and volatile, that the entire neighbourhood of a village may be infected by a single animal in a state of irritation, and in the immediate vicinity of the discharge the smell is so violent as to produce fainting fits. The specimen from which Dr Horsfield made his drawing ate voraciously of earthworms, but as soon as it had devoured ten or twelve it became drowsy, and, making a small groove in the earth, it placed its snout in it and fell asleep.

Genus Lutra, Ray. Mustela, Linn. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{5-5}$ or $\frac{5-5}{6-6}$; $= 36$ or 38. Head flat. Body long and low. Tail strong and depressed at the base.

We here place those amphibious fish-eating animals commonly called otters, of which there are many species. The character and aspect of our European kind (*Lutra vulgaris*, Erxleben, *Mustela lutra*, Linn.) are well known. It occurs over all Europe and a considerable portion of the north of Asia. It is a fierce creature, tenacious of life, and very injurious to fresh-water fisheries, from its habit of preying very exclusively on the upper parts only of trout and salmon, leaving a large portion of the caudal extremity unconsumed. What can be the nature of its objection to this despised portion? In Scotland we find the otter frequently inhabiting the sea-shore as well as the interior, and seeking its food both in salt and fresh water. The female brings forth her young, usually four or five in number, during spring. The fur is valuable, and forms an article of export from our northern isles.

The Canada otter (*L. Canadensis*, Sabine),[2] resembles the European species, both in food and habits, but it is a much larger animal, with a shorter tail, and is distinguished by the fur of the abdomen being of the same shining brown colour as that of the back. It is found across the whole of the northern parts of North America, where, during the winter season, it haunts the falls and rapids for the sake of open water, and when these are frozen over in one district, it will travel a long way in search of others, which may have resisted the power of frost. If pursued by the hunters during these peregrinations, it will throw itself forward on its belly, and slide through the snow for several yards, leaving behind it a deep furrow, and repeating this peculiar movement with such rapidity, that the swiftest runner on snowshoes with difficulty overtakes it. It also doubles on its track very cunningly, dives occasionally beneath the snow, and at last, when too closely pressed to render flight available, it will turn and defend itself with courageous obstinacy. During the spring season, on the Great Bear Lake, this species frequently robbed the nets of Sir John Franklin's first expedition, usually carrying off the heads of the fish, and leaving the bodies sticking in the meshes. It brings forth, in April, from one to three at a birth. Seven or eight thousand skins are annually imported into England.[3]

Another well known American species is the sea otter (*Lutra marina*, Steller), which Dr Fleming, on the supposition that it possesses only four incisives in the lower jaw, desires to constitute a separate genus called *Enhydra*. It is mentioned, however, in the narrative of Cook's (third) voyage, that a young sea otter had six of these teeth as usual in the lower jaw, and it may therefore be inferred that two drop out before the attainment of the adult state. The species inhabits the northern parts of the Pacific from Kamtschatka to the Yellow Sea on the Asiatic shores, and from Alaska to California on those of America. It seems to have more of the manners of a seal than of the land otter, and is sometimes met with out at sea, at a vast distance from the shore; Pennant says even as far as a hundred leagues. The fur is very handsome, and was much esteemed by the Chinese, who gave extraordinary prices for it in former days. The Canton market, however, has long been overstocked, and the influx has of course reduced the value. It varies in beauty with the age and condition of the animal, and the season of the year. Those obtained in winter are of a finer black, and otherwise more perfect than at any other period, and, according to Meares, the male is much more beautiful than the female. Those in highest estimation have the belly and throat interspersed with brilliant silver hairs, while the other parts consist of a thick black coat, with a silky gloss of extreme fineness.

Besides these northern otters we have a Brazilian species, and one (supposed to be distinct) from Carolina, while several Asiatic kinds have been described by Sir Stamford Raffles, Dr Horsfield, and MM. Diard and Leschenhault. The Cape otter (*Lutra inunguis*, F. Cuv.), is alleged to be destitute of claws, and on the supposition of the truth of that negative character, has been formed into a separate genus called *Aonyx* by M. Lesson.[4] He bestows on the sole species the name of *Delalandii*, as it was first brought from the country of the Hottentots, by the French naturalist of that name. It measures about three feet in length exclusive of the tail, which is ten inches. The fur is soft and thick, of a chesnut-brown colour, paler on the flanks, with a mixture of grey about the head. It inhabits the salt pools along the marine shores of the Cape, and preys on fish and crustacea.

2d Subdivision.

Two tuberculous teeth behind the carnivorous cheek tooth of the upper jaw. Body proportionally shorter than in the preceding subdivision, and the limbs longer.

Our present group is mainly constituted by the genera *Canis* and *Viverra* of Linnæus, including the dogs, wolves, and foxes, the civets and ichneumons, besides a few minor genera of recent introduction.

Genus Canis, Linn. Cuv. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars, $\frac{6-6}{7-7}$; $= 42$. The incisive teeth are all placed on the same line, and are usually trilobate, before being worn by use. The upper molars consist of three small single-lobed false molars, one bicuspidate carnivorous cheek-tooth, and two small tuberculous teeth with flattened crowns. The inferior molars consist of four false molars, one carnivorous cheek-tooth, and two tuberculous grinders. The tongue is smooth. The anterior extremities are furnished with five toes, the posterior with four.

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[1] *Zoological Researches.*

[2] *Zoological Appendix* to Franklin's *Journey to the Polar Sea*, p 453.

[3] *Fauna Boreali-Americana*, part i. p. 58.

[4] *Manuel de Mammalogie*, p. 157.

This genus, of such high importance as containing the numerous and various breeds of our domestic dog, is in one or other of its forms most widely spread over almost all the regions of the habitable globe. We shall not here attempt to give the peculiar characters of the *Canis familiaris*, by which general specific term, if we may be allowed the expression, naturalists are in use to distinguish the domesticated races from the wolves, jackals, and foxes, because their characters are so extremely variable in their nature, and admit of such an extended range of modification, that the exceptions to any presupposed peculiarity are almost as numerous as its confirmations. The more curved form of the tail probably distinguishes all domestic dogs from wolves, while the rounded outline of the pupil serves to separate them from the foxes, in which that organ, when exposed to light, assumes a lenticular shape. We shall proceed to a few general observations on the natural history of these animals, without attempting even an enumeration of the principal domestic kinds.[1]

The real origin of our domestic breeds whether from a single or complex source, may be said to be now entirely unknown, as a subject either of history or tradition. It is lost in the usual obscurity of a remote antiquity, and can now only be ascertained (if at all) by the investigations of the naturalist. So infinitely varied is the external aspect of these invaluable creatures, and so much does it seem to depend, not only on the physical conditions of clime and country under which they exist, but on the moral and political state of the particular nations by whom they are held in subjection, that in numerous instances all traces of resemblance to the supposed original, or indeed to any known species of wild animal, have disappeared; and after the lapse of ages, we are in fact at last presented with what may be termed artificial creatures, incapable of subsisting without the aid and companionship of man, and of which assuredly no natural type ever existed in any age or country. It is clear from what we know of the harmonious laws by which a Divine Providence regulates the economy of the animal kingdom, that no such creature as a pug dog could ever have existed as an independent being in a state of nature, or formed one of those "golden links" by which creation is so softly blended. It would have marred the immaculate beauty of the primeval world.

Many varieties, however, of the domestic dog, though originally produced by what may be termed accidents, have now become permanent subspecies, if we may use the term, each of which is signalised by some characteristic peculiarity of either a physical or instinctive nature, and differs from an ordinary variety (as exhibited among unreclaimed animals), in the power which it possesses of reproducing individuals exactly similar to itself. Several of these varieties from their great value to mankind, have been so encouraged and preserved in purity, as to have become impressed with characters not only distinctive, but of so uniform and permanent a nature as to exhibit in certain instances the aspect of a total difference in kind. Making due allowance, however, for the influence of all extraneous or accidental causes, we yet deem it impossible to doubt that the origin of the dog tribe, as it now exists under the extended dominion of mankind, has been rather complex than simple. We do not mean to maintain that every strongly marked variety has had each its own original source, or that even when nature

> "Wanton'd as in her prime, and play'd at will
> Her virgin fancies,"

there ever existed wild greyhounds, unreclaimed pug dogs, or native pointers and poodles, all alike independent of each other, and of their now acknowledged lord and master, because the question in that case would, from their multiplicity, be speedily set at rest by the occurrence of one or other of these animals in its original and unsubdued condition. But we think it improper to refer the various breeds to one and the same origin, the theory seeming to ourselves more natural which supposes that the characteristic kinds, or great leading varieties of each country or continent, have either directly descended from, or been crossed and remodelled by a union with, such of the native (canine) animals of the same natural genus, as we still find to occur in such country or continent. For example, although we may admit with Guldenstaedt, that the Kalmuc, and some other eastern dogs, may have derived their origin from the jackal, the same cannot be said of those of New Holland, or of North and South America, where the jackal is unknown; and several of our own northern varieties are evidently descended so much more immediately from the wolf, as to render the ancestral aid of the "lion's provider" altogether superfluous. We also know that in America and New Holland, at the period of (and consequently prior to) the discovery of these countries by Europeans, there existed both wild and domesticated dogs, the former of which were evidently indigenous, and in all probability the origin of the latter.[2]

We believe that Pallas was among the first to give currency to the opinion that the dog was to be regarded in a great measure as an adventitious animal, that is to say, as a creature produced by the fortuitous and diversified alliances of several natural species. Both the shepherd's dog and the wolf dog, in his opinion, derive their origin from the jackal, while the mastiff is regarded as more nearly related to the hyena, and the smaller tribes of terriers, &c. to the fox, His ideas, though somewhat fanciful, merit the attention of the naturalist. We object, however, to the hyena, which (though classed with the dogs by Linnæus) is not in fact a canine animal, but belongs to a distinct and well-defined genus, characterized by having five toes on each foot, and five molar teeth on either side of both jaws; whereas the truly canine race, such as dogs, wolves, and jackals, have only four toes on the hinder extremities, with six molar teeth on each side of the upper jaw, and seven on each side of the under. The general proportions of the hyena, too, are very different, the fore-legs being longer than the hind ones, which has the effect of raising the shoulders and anterior portion of the body; whereas in the other species just named, the hind legs are longer than the fore ones, a character which probably obtains among all swift-footed animals. The immediate relationship of the fox is likewise doubtful. His alliance would be useful as giving the *earthy* propensities of the terrier tribes, but we cannot overlook the peculiar shape of the pupil, which is what naturalists call nocturnal, that is oblong, and narrowing under the influence of light; whereas in dogs and other canine species, though it decreases in size under that influence, it retains its circular form. The difference in the habitual character and instinctive habits of the fox must also be borne in mind. It is scarcely necessary to say that it is a wary, silent, nocturnal animal, of sly and solitary habits, never congregating, or hunting its prey in packs, but preferring a gradual and unperceived approach, and the exercise of an insidious cunning, to the more open warfare declared by its congeners. This distinction is in truth of greater importance than may at first appear, for we consider the social or gregarious sentiment in animals as the true basis of a thorough domestication. A solitary species, may, indeed, be tamed, so far as the individual is concerned, but if the social instinct is wanting, its descendants will be only half reclaimed, and the process must be again resorted to. But the love of society, which we call the social instinct, and which is so strongly possessed by sheep, oxen. and other domestic kinds, when once properly directed towards himself by the skill of man, renders these animals forever both attached and subservient to the human race. Another strong objection, though of a more negative kind, to the theories of Pallas and Guldenstaedt, is founded on their slight consideration, if not entire exclusion, of the wolf as the most probable parent, especially in northern countries, of a numerous and important tribe of our domestic dogs. In reference to the point at issue, we indeed regard this animal, as of all others, the most entitled to our strong attention. Many well known varieties of the dog exhibit so wolfish an aspect, that their descent from that species, at a more or less remote period, can scarcely be doubted; and we incline the more to this opinion, when we consider that the jackal is not a northern animal, that the wolf is eminently so; and that the remotest tribes of the human race, inhabiting the highest northern latitudes, have never been found unaccompanied by a domesticated breed of dogs, bearing a greater resemblance to the wolf than to the jackal.

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[1] We have given a more extended view of the origin and natural history of domestic dogs in the 5th and 6th numbers of the *Quarterly Journal of Agriculture*, and in the first volume of our *Illustrations of Zoology*. genus *Canis*. The reader will find a valuable paper (by another hand) on sporting dogs, under the term HOUND, of this Encyclopædia. See volume xi. p. 762.

[2] For Humboldt's opinion of the indigenous dogs of South America, see *Personal Narrative*, vol. ii. part 2.

All the principal and regulating facts in the natural history of the wolf and dog are identical. The rutting season commences at the same time, and continues for an equal period in each; and both carry their young for nine weeks,—Gilibert's opinion that the period of the wolf's gestation extended to three months and a half having since been proved to be erroneous. Then the jackal is a puny and powerless creature, compared with many of its alleged descendants, while the wolf is one of the strongest of European carnivorous animals. Though those of Spain and Italy are not gigantic, the wolves of Lithuania are extremely large, frequently measuring five feet in length from the muzzle to the insertion of the tail; and the same, or even increased dimensions are maintained by those of still more northern climes. Both their coat and colour vary in accordance with the climate. In high northern latitudes they become white in winter, and a black variety occurs in Spain. This natural variation of the colour of the wolf is a circumstance of some importance in relation to the present inquiry, because the tendency to become white at one extremity of the series, or range of colours, and black at the other, combined with what may be called the central or representative hue of the animal, which is brown, supplies in fact the three elementary colours of the whole tribe of dogs, and thus in a great measure accounts for the variety of markings by which our domestic races are distinguished. In a state of domestication the wolf is capable of assuming and retaining all the docility and gentleness of the dog, and the productive union of the two, though at one time doubted by Buffon, was at an after period ascertained and demonstrated by that brilliant historian of the brute creation, and has since been frequently confirmed in recent times. We shall here rest satisfied with a single citation: "Those naturalists," says Captain Sabine, "who believe that no animal, in a perfectly natural and wild state, will connect itself with one of a different species, will consider the long agitated question of the specific identity of the wolf and dog, as determined by a circumstance of frequent occurrence at Melville Island. In December and January, which are the months in which wolves are in season, a female paid almost daily visits to the neighbourhood of the ships, and remained till she was joined by a setter-dog belonging to one of the officers. They were usually together from two to three hours; and as they did not go far away, unless an endeavour was made to approach them, repeated and decided evidence was obtained of the purpose for which they were thus associated."[1]

Now the only reasonable objection which, as it appears to us, remained to the experiments of Buffon and the younger Cuvier, was deducible from the fact of these having been made upon animals in confinement, and which were consequently existing under constrained and artificial circumstances. But here such objection ceases. We witness the *voluntary* cohabiting of two creatures brought up under entirely different circumstances,—the one with as much of wildness as the most forlorn region of the earth could induce upon an originally savage nature, the other so altered in its form and aspect by the immemorial subjection of itself and ancestors to the dominion of man, as to have lost almost all outward resemblance to the stock from whence it sprung; and yet, notwithstanding this disparity of manners, and the different conditions of the social state, they mutually recognise and acknowledge each other, and the immediate representative of the natural and unaltered species, "like the wild envoy of a barbarous clan," seeks and obtains the affection of the enslaved descendant. Unless all our established notions regarding the legitimate distinctions of species are essentially false, what more do we require to prove the identity of the animals in question?

It is also of importance to bear in mind the existence of wild dogs of the domestic breed, which live in a fierce and emancipated state in the plains and forests of many different countries, because this fact demonstrates that no changes, either physical or artificial, on the earth's surface, whether produced by the agency of man or otherwise, can have extinguished the original source, when its descendants, after regaining their liberty, are thus found to breed and prosper in a state of nature. We insist the more upon this observation, because we think it cuts deeply at the base of a theory, or rather hypothesis, maintained by certain naturalists, who, unable in any way to disencumber the subject, give it the slip by asserting that we must now for ever seek in vain for the original type of our domestic races, in consequence of its extinction, either by universal servitude, or actual extermination. Now, it would certainly be surprising if the original source of the plurality of our domestic dogs had ceased to exist in an independent state, when we see the wild species of so many of our other domestic animals still flourishing in their original positions, notwithstanding their more confined limits, the smaller number of their young, and their comparatively defenceless nature. Those troops of wild (emancipated) dogs which we know to exist in the midst of European colonies, in spite of continued efforts to destroy them, prove that in the infancy and early progress of human society, a naturally wild species could neither be entirely subdued, nor utterly exterminated. Nor is there any evidence whatever from history, tradition, or the geological phenomena of nature, of the extinction of any wild animal of the dog kind; and, as ancient writers mention all the actual species of that tribe in the countries where they still exist, it may more reasonably be concluded that one or more of these wild species are the actual source of our various domestic breeds, than that the source itself has been extirpated.

It is proper, while endeavouring to trace the origin of what Baron Cuvier has called "the completest, the most singular, and the most useful conquest ever made by man,"[2] more especially when we know how ancient that conquest must have been, to refer to the native species of the country usually regarded as the cradle of the human race. From the earliest periods of which we have any detailed records down to the more minutely authenticated histories of modern times, there has never been any indication given of the existence, in Asia Minor, of more than four wild animals of the dog tribe, viz. the hyena, the wolf, the fox, and the jackal. The first of these species, we have already stated, is not now regarded by naturalists as pertaining to the canine race, and we have also referred to certain strongly marked distinctive peculiarities of the fox; so that we consider the wolf and jackal as alone entitled to our particular regard in relation to the present inquiry. We have already said enough to shew the strong claims of the wolf, so far as the northern races are concerned; but the multiplicity of size, form, and locality of our domestic dogs, seems to indicate a compound origin, and it cannot be denied that many of the southern dogs present so marked and peculiar a character, that their descent from the jackal is obvious. It is not our province to enter in this place into anatomical details, but we may state generally, that an attentive comparison scarcely exhibits any sensible difference between the internal structure of the jackal and that of the shepherd's dog. This is the opinion espoused by Pallas and Guldenstaedt, the former of whom maintains that the dogs of the Kalmuks are in truth neither more nor less than jackals. This animal has always abounded in Asia Minor, where all the theogonies of the west have placed the paradisaical cradle of the human race, and where it must have been easily accessible to the first families of mankind. We willingly coincide in this view, with the reservations before mentioned regarding the great northern dogs, and those of the still remoter countries of the New World, where the jackal is unknown, but where its place is amply filled by gaunt and grizzly wolves. It is, indeed, by no means likely that the dogs mentioned by Pietro Martyro and Oviedo, as living with the inhabitants of the little Antilles and the Caraibs of Terra Firma, were derived from species foreign to America; because the authors first named (both of whom were contemporaneous with and witnesses to the discovery and conquest of America) describe these dogs as being of various colours and kinds of coat, from which we may infer that they had been, even then, for a long period reduced to servitude. They were all mute; that is to say, they never barked: but that faculty seems, in truth, to be neither natural nor innate, but rather acquired by habit, as domestic dogs run wild have no other cry than a sharp or prolonged howl; and the silent species of barbarous nations, when introduced into civilized society, speedily acquire the bark of our domestic kinds.

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[1] *Supplement to the Appendix to* Parry's *First Voyage*, p. 185.

[2] *Règne Animal*, t. i. p. 149.

It may, moreover, be borne in mind, that there are at least two kinds of jackal,—the better known species, commonly called the Indian Jackal (*Canis aureus*, Linn.), and that from Senegal, described by Frederick Cuvier under the name of *Canis anthus.* These animals, though regarded as specifically distinct, have bred together in the Garden of Plants. This is a fact of considerable importance, as shewing the facility with which a mixed breed from the jackal might be procured; and as it was previously known that the wolf manifested the same instinctive inclination towards different varieties of the dog, we thus obtain a more extended knowledge of a feature in the character of the canine race, which throws considerable light upon our inquiries. When we see that both the wolf and jackal thus breed with other species, and that all our domesticated dogs breed with each other, although some are scarcely distinguishable from the wolf, while others seem identical with the jackal, we can scarcely doubt that all such domesticated varieties have in fact arisen primarily from these two animals,—the southern from the jackal, the northern from the wolf; and that the intermediate varieties have sprung from an intermixture of the jackal-dogs on the one hand, and of the wolf-dogs on the other, afterwards crossed and commingled in various conceivable ways, both by accident and design. We confess that the extreme variations are still surprising, if not unaccountable; such as the difference between a lofty limbed and almost gigantic stag-hound of the ancient Irish breed, and the low-legged waddling turnspit, or terrier of the Isle of Skye; but that domestication for many thousand years, and the altered habits of life which ensue from it, have been strongly influential in moulding the form and character of the canine race, is evident from this, that the dogs of all wild and secluded nations, whose domestic animals may be supposed to exist most nearly in a state of nature, are all more strongly allied either to the wolf or the jackall, than those that partake the fortunes of civilized men, who dwell in large cities, or in thickly peopled countries; and this approximation to the aspect of the wild animal in the one case, and departure from it in the other, is in truth the surest index to the primitive types which it is possible to obtain. Thus from two or three original sources or distinct kinds, have been derived about ten times the number of mixed races,—many of which, and chiefly those which lead the most artificial or altered modes of life, have now lost all traces of resemblance to the stock from which they sprung.

The length of the preceding observations will prevent our entering into any detailed account of the infinitely varied dogs of the domestic kind. The subject is, indeed, far too extensive for our present limits, for there is scarcely a nation of the earth, savage or civilized, that does not benefit by their friendly assistance, or derive delight from their affectionate companionship. We doubt not that many tribes of mankind would cease to exist if their dogs were withdrawn from them, and we know of scarcely any which would not suffer severely from such deprivation. Their strength, activity, and courage,—their intelligence, perseverance, and attachment—their exquisite sense of smell—their finely accommodating instincts, and, in many cases, their extreme beauty and grace,—have deservedly rendered the canine tribe the objects of the most unfeigned wonder and admiration to all observers and narrators, whether of ancient or modern days, from Hippocrates to the Ettrick Shepherd.[1]

Having figured, as an illustration of the present genus, the Hare Indian, or Mackenzie River dog (*Canis familiaris*, var. *lagopus* of Richardson, see Plate V., figure 4), we shall here conclude with a few lines in explanation of its history and habits. This variety, as far as yet known, is cultivated only by the Hare Indians and other tribes that frequent the borders of the Great Bear Lake, and the banks of the Mackenzie River. It is too small to be used as a beast of burden, and is therefore employed solely in the chase. It has a mild and demure countenance, a small head, slender muzzle, erect thickish ears, somewhat oblique eyes, rather slender legs, broad hairy feet, and a bushy tail. Though it is covered with long hair, intermingled at the roots with a deal of wool, it differs from the American foxes, and agrees with the wolves, in always having callous protuberances, even during winter, on the soles of the feet and at the roots of the toes. Its size is inferior to that of the prairie wolf, but rather greater than that of the red fox of America. Its resemblance, however, to the former is so great, that, on comparing live specimens, Dr Richardson could detect no decided difference in form (except the smallness of the cranium), nor in the fineness of the fur, nor even in the arrangement of the spots of colour. It bears, in fact, the same relation to the prairie wolf that the Esquimaux dog does to the great grey wolf of the northern parts of the New World, a fact which affords an interesting confirmation of the general views contained in the preceding paragraphs. The Hare Indian dog is very playful and affectionate, and easily attached by kindness. It is, however, not very docile beyond the range of its immediate instincts, and has a great dislike to confinement. Its voice, when injured or afraid, is that of a wolf, but when merely excited or surprised, it makes an attempt to bark, usually ending, however, in a kind of howl. For its size, it is extremely swift and strong. A young one purchased by Dr Richardson from the Hare Indians, became greatly attached to its master, and when not more than seven months old, ran by the side of his sledge upon the snow, for 900 miles, without fatigue. During this long journey, it often carried, of its own accord, a glove in its mouth for a mile or two; but though gentle in its manners, it exhibited but a limited love of learning, and made no progress in fetching and carrying comparable to that of the Newfoundland dog, or many other kinds. It was at last unfortunately killed and eaten by an Indian on the banks of the Saskatchewan, who pretended that he *mistook it for a fox*,—a reason which, according to our European notions, would not so much have led to as deterred from such a meal.[1]

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[1] The reader who desires a knowledge, or at least a notion of domestic dogs of various kinds, will consult with advantage (in addition, of course, to the various sporting Annals of our own country), Mr Griffith's valuable English edition (with additions) of the *Règne Animal*—the *Menageries* (vol. i.) of the *Library of Entertaining Knowledge*—our essay "On the Origin and Natural History of Dogs" in the *Quarterly Journal of Agriculture* (5th and 6th Nos.)—and Captain Brown's Compendium entitled *Anecdotes of Dogs.*

We shall now say a few words regarding wolves. The common wolf (*Canis lupus*, Linn.) is the fiercest and most carnivorous of the wild animals yet indigenous to Europe. It resembles a large lank-faced, ill-conditioned dog, with a straight tail, a coat of a greyish-fawn colour, and in the adult state, a blackish streak upon the anterior legs. It varies, however, considerably, both in size and colour, according to the nature of the different localities in which it occurs, being larger and fiercer in more northern and unpeopled countries,—feebler and of smaller size when surrounded by enemies, and living in a state of continual fear and precaution. He wanders about in summer during the morning and evening twilight in search of food, which in a sufficing quantity he seldom finds. Frogs, field-mice, and the putrid remains of larger animals, are not despised. The rutting season of the female is in January. She is then followed by numerous males, the strongest or boldest of which having driven away the others, becomes her companion, and seldom quits her till the young have completed their education. When about to bring forth, she prepares her den in some sheltered and secluded spot, which she furnishes with leaves, dried grass, and a portion of wool or hair from her own body. The number of her litter varies from five or six to nine, and the young are born with their eyes closed. For several days the mother never quits them, she herself being carefully fed by the male. She suckles for two months, but about the end of the fifth or sixth week she disgorges half-digested food, and soon after accustoms them to kill and feed upon small animals which she has previously captured. It has been observed that, during this period, the young are never left alone, but are always guarded by one or other of the parents. In about two months they lead them from the covert, and initiate them in the mysteries of the chase. In November or December they begin to wander forth by themselves, but they usually remain more or less united in one family, till the parents are obliged to prepare for another brood.

The wolf in a wild state is a cowardly though cruel animal. He has sometimes been observed so stupified by sudden fear as to be killed or secured alive without danger or difficulty. At the same time, when pressed by hunger, and assembled in troops during the winter season, they become formidable both to man and beast. We know from the ancient chroniclers, and from various legal enactments and feudal tenures, how greatly Britain, especially Yorkshire, was infested by wolves during the days of our Saxon ancestors; and that in the reign of Athelstane it was found necessary to erect a kind of retreat at a place called Flixton, for the protection of passing travellers. Wolves, however, appear to have become almost extinct in England as far back as the termination of the thirteenth century, at least we do not find them recorded as a nuisance after the year 1281. "It is none of the least blessings," observes Hollinshed, "wherewith God hath indued this island, that it is void of noisome beasts, as lions, bears, tigers, pards, wolfes, and such like, by means whereof our countrymen may trafelle in safetie, and our herds and flocks remain for the most part abroad in the field without anie herdsman or keeper. This is chiefly spoken of the south and south-west parts of the island. For whereas we that dwell on this side of the Tweed, may safelie boast of our securitie in this behalfe: yet cannot the Scots do the like in everie point within their kingdome, sith they have grievous wolfes and cruell foxes, besides some other of like disposition continuallie conversant among them, to the general hindrance of their husbandmen, and no small damage unto the inhabiters of those quarters."[2] According to the same authority, the extirpation of wolves from England was imposed as a tribute by king Edgar upon the conquered Welsh. Ludwal, prince of Wales, paid yearly a tribute of 300 wolves, so that in four years none were left. The last seen in Scotland was killed by Sir Ewen Cameron in the year 1680. In Ireland the species was not totally extirpated till about thirty years after that period.

In a state of domestication the wolf can be regarded as nothing more than a dog of a somewhat anomalous and unusual aspect. M. F. Cuvier has more than once rendered them so tame and docile, that but for their unextinguishable love of live poultry, they might have been allowed to wander where they chose. They associated freely and fondly with common dogs, and speedily acquired from them the habit of barking. In general, however, and when left free to manifest their natural instinct, dogs exhibit a great aversion to wolves; and the latter, according to Hearne, frequently slay and devour the train dogs of the Esquimaux. Captain Lyon, who describes the wolves of Melville Peninsula as comparatively fearless, states, that one afternoon a fine dog having strayed a short way ahead of its master, five wolves made a sudden and unexpected rush upon it, and devoured it in so incredibly short a time, that before the gentleman who witnessed the attack could reach the scene of action, the dog had totally disappeared with the exception of the lower part of one leg. In those forlorn regions they frequently came alongside the frost-bound ship, and one night broke into a snow-hut, and carried away a brace of Esquimaux dogs, which appeared to have made a vigorous though unavailing resistance, the ceiling being all besprinkled with blood and hair. So strong, as well as ferocious are these blood-thirsty creatures, in spite of what one might suppose the subduing influence of intense cold, that when the alarm was given, and an armed party proceeded to attempt a rescue, one of the wolves above alluded to was observed, when fired at, to take up a dead dog in his mouth, and to set off with it at an easy canter, although the weight of the victim was supposed to be equal to his own.[3] These and similar facts, apparently of a nature contradictory to the theory of an identity of species which we have previously proponed, is, in truth, in proper accordance with what we know takes place among many other animals, when wild and tame individuals chance to encounter. A strongly marked jealousy, if not positive enmity, seems to exist between the unsubdued members of the same species and such as have passed beneath the yoke. It may be supposed to result, not unnaturally, from that perception of "similitude in dissimilitude" which, according to circumstances, leads alike to the extremes of love or hatred. We have already alluded to the strong instinctive affection which in due season has been seen to exist between them, and we certainly do not conceive that, from a few chance murders rendered almost imperative by the pressure of the times, an argument of any value can be deduced against the natural identity of the wolf and dog.

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[1] For an excellent account of this, as well as of the other dogs of North America, see *Fauna Boreali-Americana*, part i. p. 79.

[2] *Chronicles*, vol. i. p. 378

[3] *Private Journal*, pp. 151, 339, &c.

The black wolf of Europe (Canis *Lycaon*, Linn. *le loup noir*, Buff.) differs very slightly from the common brown species except in colour. Its ferocity, however, is said to be greater. It occurs accidentally in France,—more frequently in Spain and the Pyrenean range. There were two of these black wolves some years ago in the menagerie of the King's Garden in Paris, which every season brought forth young as fierce and mistrustful as themselves, but not like their parents in their colour and external markings. From this circumstance we would hesitate to regard the black wolf as more than an accidental variety. Indeed it has been regarded by some as a mixed race, originally sprung from the common wolf and a black dog run wild among the woods or mountains. The American Indians do not regard the black wolves as distinct from the others, although they abound on the banks of the Missouri, and they report that one or more of that colour are occasionally found in the litter of the common kind.

In regard to the wolves of the New World in general, naturalists do not quite accord in their enumeration of the species. A brown wolf, described as possessing all the characters of the European kind, is said to exist within the limits of the United States; but the more northern American species, though they may possibly approximate those of Siberia and of Lapland, certainly differ greatly in their general physiognomy from the natives of France and the Pyrenees. They are of a more robust and larger form, their hair is longer, finer, and more woolly, their muzzle thicker and blunter, their head larger and rounder, with a sensible depression at the union of the nose and forehead. Except in their superior size and strength, the North American wolves so greatly resembled the sledge dogs of the natives, that our arctic travellers more than once mistook a band of these predaceous animals for the domestic troop of an Indian party. The howl of each is precisely the same.[1] When the deep and long enduring snows of winter have entombed the face of nature in their silent shroud, these creatures often suffer dreadfully from famine, and were they not for the most part as fearful as rapacious, they would assuredly prove most unpleasant neighbours. But the simple expedient of tying an inflated bladder to a branch, so as to admit of its waving in the wind, is sufficient to keep a whole herd at a distance. At times, however, they become more venturous; and at Cumberland House, in 1820, a wolf which had been seen prowling around the fort, and was shot at and severely wounded by a musket-ball, returned again in the dark, streaming with blood, and carried off a dog among fifty others,—the latter howling piteously, but unable to summon courage to attack the gaunt intruder. Sir J. Richardson was even told of a poor Indian woman having been strangled by a wolf, while her husband, who saw the onset of the animal, was hastening to her assistance; but their destruction of human life is most extremely rare. In the spring of 1826, a large grey wolf was driven by hunger to prowl among the huts which had been erected in the vicinity of Fort Franklin, but he attacked no one, and being unsuccessful in obtaining food, he was found a few days afterwards, lying dead upon the snow. This specimen is now in the Edinburgh College Museum, and is exhibited in Plate V., figure 3, of the present work.[2]

We have already alluded briefly to those other canine animals called Jackals, of which there are at least two species. The Asiatic kind *(Canis aureus)*, commonly called the Lion's Provider, occurs over a great extent of territory from India to Palestine, and from Egypt and Barbary, along the shores and through the deserts of Africa to the Cape of Good Hope. Its great voracity, gregarious habits, and wild nocturnal cries, are well known to eastern travellers. It hunts in packs, and the king of beasts, when roused from his royal slumbers by the yells of these insatiate creatures in pursuit of prey, probably follows the hue and cry, and ere long coming up with the slaughtered quarry, comes in for more than a monarch's share of deer or antelope, to the no small chagrin of his so-called providers. The Senegal kind (*Canis anthus*) is characteristic of the western shores, and the Cape jackal *(C. mesomelas*, by some regarded rather as a fox), is found more exclusively at the southern portion of the continent.

Our next group of canine animals contains the Foxes. These may be distinguished both from dogs and wolves by their longer and more brushy tails, their pointed muzzle, and the vertical pupils of their cunning eyes. They also exhale a much more fetid smell. They are of smaller size, but much more numerous in amount of species. On the well-known aspect and character of our common kind (*Canis vulpes*, Linn.) we need not here enter, but shall briefly notice a few of the foreign species.

The arctic fox (*Canis lagopus*) inhabits the most northern lands hitherto discovered. It breeds on the sea coasts, chiefly within the arctic circle, forming its burrows in sandy spots, not isolated as with us, but in little villages of twenty or thirty adjoining. It resembles our European fox in form, but is more densely clothed, of smaller size, and changes its colour in winter from bluish-brown to white. Its fur is of small value compared to that of the red fox, but its flesh, when young, is eatable; while, as an article of food, the other species is extremely disagreeable. The sooty dog of Pennant,[3] and the blue fox described by Sir George Mackenzie,[4] are merely varieties of this arctic species.

The red fox of North America (*Canis fulvus*, Desm.) inhabits the woody districts of the fur countries. About 8000 skins are imported into England every year. Pennant, and most authors of the last century, regarded this species as identical with our common European kind; but its peculiarities have since been pointed out by M. Palisot de Beauvois. It is distinguished by its longer and finer fur, and more brilliant colouring. Its cheeks are rounder,—its nose thicker, shorter, and more truncated,—its eyes are nearer to each other, and its feet generally much more woolly beneath. It has a more copious brush, and is altogether a larger animal. Yet it does not possess the enduring speed of the British renard, its strength appearing to be exhausted at the first burst, after which it is easily overtaken either by a mounted huntsman, or its enemy the wolf. The red fox preys much on small animals of the rat kind, is fond of fish, and in fact rejects no animal substance of any kind. The American cross fox (*Canis decussatus*, Geoff.) is probably a variety of the preceding, although it is usually of smaller size. Its fur is much esteemed, a single specimen not many years ago being worth from four to five guineas, while that of the red fox did not bring more than fifteen shillings. A rarer and still more valuable variety is the black or silver fox (*Canis argentatus*, Desm.), of which never more than four or five individuals are taken at any one post of the fur countries throughout the year, although the hunters leave no device untried. It varies from a mixed or hoary hue to a shining black. La Hontan says, that in his time the skin of a black fox was worth its weight in gold, and it still fetches six times the price of any other fur obtained in North America. Various additional species of the fox tribe have been described by naturalists.

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[1] "The offspring of the wolf and Indian dog are prolific, and are prized by the voyagers as beasts of draught, being stronger than the ordinary dogs."— Sir G. Back's *Narrative*, Appendix, p. 492.

[2] For the other wolves of North America, see *Fauna Boreali-Americana*, Part i., and Harlan's *Fauna Americana*. Several species occur in the more southern parts of the New World, such as the Mexican Wolf, the Red Wolf of Paraguay, &c. For these see Desmarest's *Mammalogie*, Cuvier's *Ossemens Fossiles*, and Azara's *Essai sur les Quadrupedes de Paraguay*.

[3] *History of Quadrupeds*, vol. i. p. 257.

[4] *Travels in Iceland*, p. 327.

Genus Megalotis, Illiger. *Fennecus*, Desm. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{?-?}$; $=?$ Muzzle pointed. Ears extremely large. Four (?) toes on each foot.

Great contrariety of opinion has existed among systematic naturalists regarding the nature and affinities of the animal described by Bruce, the Abyssinian traveller, under the name of *fennec*,—the *Animal anonyme* of Buffon; and we regret to say, that in addition to merely scientific discussion, some not very amiable inferences have been deduced by that spirit of rivalry, which though useful as an exciting motive, and as a disturber of lethargy, is sometimes apt, in acrimonious minds, to overflow the bounds of Christian charity. The discovery of the animal in question, though usually assigned to Bruce, was likewise claimed by a Swedish gentleman, M. Shioldebrand, who is asserted by the former to have got the start of him in this matter by some petty artifice. Neither the one nor the other, however, it has been observed, has described the species with such a degree of scientific accuracy as to afford us any aid in determining its true position in the system, and the consequence has been, that each subsequent writer has placed it in a different genus. Some have classed it with the cats, others among the canine tribes. Illiger made it the type of a new genus, under the name of *Megalotis* (which we here adopt), while it has been occasionally placed with the squirrels in the order *Glires*, and was even at one period published by the skilful G. St Hilaire as a quadrumanous animal, belonging to the genus *Galago!* Although thus known under a sufficient number of appellations, it is nevertheless most commonly called the "Anonymous animal," as if it had no name at all; and while one writer describes it as inhabiting the desert wastes of the Sahara, where it is alleged to excavate for itself a subterranean dwelling, another assures us that it dwells habitually amid the plumy summits of the loftiest palm-trees. In consequence of these contradictory statements, some later authors seem inclined to deny its existence altogether, while others allege that the so called anonymous animal constitutes in fact a distinct genus, consisting not of one but of two easily distinguished species.

Buffon is known to have published his figure of the fennec from a drawing transmitted to him by Bruce. As the views of the great French writer were extremely fanciful in relation to arrangement, we need not be surprised that he should have placed it between the squirrel and the hare. It certainly has long ears and a somewhat bushy tail; and we have seen enough of what are called *affinities* in modern times, to palliate the vagaries of our imaginative predecessors. Blumenbach, from Bruce's description, refers it to the civets. Sparrman maintains its identity with a species of the south of Africa called *Zerda*,—in consequence of which it continues to bear that name in many systematic works. Desmarest follows Illiger in making it the type of a new genus,—the name of which, however, he changes to *Fennecus*. We need scarcely say, that by these repeated transpositions but a feeble light was thrown upon its actual nature. More recently, however, the Museum of Frankfort was visited almost simultaneously by two intelligent zoologists, M. Temminck and Dr Sigismond Leuckart of Heidelberg, both of whom immediately recognised the fennec of Bruce in an animal then recently transmitted from Dongola by the traveller Rüppel. As the result of their investigations, and of those of others since continued, to which we have had private access, there now remains no doubt that the fennec is closely allied to the canine race, being most related to the subdivision which contains the foxes, and approaching particularly to the *Canis corsac*. The teeth, the feet, the number of toes (?), and the form of the tail, are said to be the same as those of a fox;—but the limbs are higher and more slender in proportion. The aspect of the head is rendered peculiar by the extraordinary size of the ears. Our information is still defective regarding the manners of this species, but it appears to be the opinion of those who have studied its character and history, that the fact reported by Bruce of its living on trees is erroneous, and that it is more probably a ground or even a subterranean animal, supporting itself, in a state of nature, on small quadrupeds and birds.[1] Of the individual observed by Bruce the favourite food was dates, or any other sweetish food; yet it was observed to be very fond of the eggs of small birds. When hungry it would eat bread, especially when spread with honey; but when a small bird passed near, it was observed to engross for a time the fennec's whole attention, and to be followed, while within the range of sight, with eager eye. It became unquiet and restless as soon as night came on, from which we may infer a nocturnal nature. Its body measured about ten inches long, the tail five, the ears three. The pupil of the eye was large and black, and surrounded by a deep blue iris. It had a sly and wily aspect, but as its habits are not gregarious, and for other reasons, Bruce doubts the propriety of this creature being regarded as the *Saphan* of the Scriptures,—an opinion advocated both by Jewish and Arabian writers.

The genus now consists of two species, the fennec of Bruce, above alluded to (*M. Brucii*, *Canis zerda* of Gmelin), which will be found figured in Plate V., figure 6; and Delalande's fennec (*M. Delalandii*, Smith, *Canis megalotis*, Cuv.), which is native to the Cape of Good Hope.[2]

We may notice in this place another singular canine animal from the Cape, which seems to have likewise received a multiplicity of names. It occupies, as it were, a station intermediate to that of the dogs and hyenas, and although long known to the colonists under the designation of wild dog, and alluded to by many travellers, its distinctive peculiarities were first pointed out by Mr Burchell, who describes it under the name of *Hyæna venatica*.[1] In the number of its teeth it agrees with the dogs, but it has only four toes on the anterior feet, and its body is hyæna-like in its form, being considerably higher before than behind, with the joints of the carpus very weak. If classed with the true dogs, its most appropriate title would be *Canis hyænoides*, but it is understood that Mr Brooks (in whose splendid museum there existed a skeleton of the animal) regarded it as a distinct genus, and we find it recorded as such under the name of *Lycaon tricolor*.[2] The general colour of this animal is a sandy bay or ochreous yellow, shaded with darker hairs, and the entire body is blotched and brindled with black and white spots. Mr Burchell kept a specimen for thirteen months chained up in a stable-yard, but its nature was ferocious, and although at last it began to gamble occasionally with a common dog, yet its keeper never dared to touch it with his hand. In its native state it hunts in regular packs, both by day and night, and is so rapid in its movements, that none but the swiftest animals can ensure their safety. Sheep fall an easy sacrifice, but the larger cattle are seldom attacked, except stealthily from behind, for the sake of snapping off their tails,—the want of which, our readers may be assured, in a warm country, swarming with hide-piercing insects, is the source of most serious distress to any quadruped. "In the morning," says our traveller, "Philip returned with the oxen; but reported that, in consequence of Abram Abram's neglecting in the night before to secure them as usual in the cattle-pen, the *wilde honden* (wild dogs) had bitten off the tails of three. One had only lost the brush, but the others were deprived of the whole!" The animal in question is of a more slender form than either the striped or the spotted hyæna.

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[1] *Edinburgh Cabinet Library*, No. xii. p. 390.

[2] For figures and descriptions of these animals, see Bruce's *Travels*, plate 28; Griffith's *Animal Kingdom*, vol. ii. p. 372; and Ruppel's *Reise im Nördlichen Afrika*, pl. 111. The ears in Bruce's figure are too large.

GENUS VIVERRA, Linn., Cuv. Incisors $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; = 40. The lower incisives are placed on the same line, and the canines are rather strong. The upper molars consist, on each side, of three false molars, slightly conical and compressed, of a large carnivorous cheek-tooth, sharp, cutting, and tricuspidate, and of two tuberculous grinders. The lower jaw presents four false molars on each side, a strong carnivorous bicuspidate cheek-tooth, and a single very broad tuberculous grinder. The head is long, the muzzle pointed, the pupil narrow when contracted, and the tongue covered by corneous papillæ. Each foot is furnished with five toes, and the claws are semi-retractyle. The tail is long and covered with hair.

This genus, as now restricted (the ichneumons no longer forming one of its constituent portions), contains the animals commonly called *civets* and *genets*, all remarkable for their musky odour. They are peculiar to the warmer countries of the ancient world, and their habits, in a state of nature, are as yet but slightly known.

The civets properly so called (VIVERRA, Cuv.), are distinguished by a deep anal pouch divided into two interior sacks, and filled with a musky pomade, of considerable commercial value as an article of perfumery. The species occur both in Asia and Africa. Enfras, a town of Abyssinia, is said to carry on an extensive civet trade, great numbers being there kept in a state of confinement. The *V. civetta* and *zibetha* of Linnæus are still insufficiently distinguished. They are very closely allied to each other, but the former is said to be characteristic of Africa, the latter of the East Indies. Dr Horsfield has described a third species called *Rasse* by the Javanese. Its appetite is very sanguinary in a state of nature, and leads it to prey on birds and quadrupeds. In confinement it agrees well with a mixed diet of rice and animal food. It yields the odoriferous substance called *dedes* in Java, the *jibet* of the Malays. This perfume is a great favourite in Java, where, during festal days and public processions, the air is diffusively filled with its odour. Salt is said to be a poison to the animal which yields it.

In the group or subgenus called genets (GENETTA, Cuv.) the anal bag is reduced to little more than a fold of the skin, and the secretion is very slight, though there is a sensible exhalation of a musky odour. The pupil, when exposed to light, is vertical, and the claws are almost as retractile as those of cats. The common genet (*V. genetta*, Linn.) is a European species, widely extended in its distribution from the south of France to the Cape of Good Hope. It varies considerably in its markings, and its fur forms an article of commerce. Other species occur both in Africa and the East. The rare Javanese animal the *Delundung*, which seems in some respects intermediate between the viverræ and the cats (it forms the genus PRIONODON of Dr Horsfield), is ranked by Baron Cuvier with the genets.

We may here briefly notice a peculiar species long known to systematic writers under the name of palm marten and *Genette de France*. Its dentition and the majority of its other characters agree with those of the genets, but its form is thicker, its toes semi-palmate, and its walk almost plantigrade. Its most peculiar character, however, consists in the form of the tail, which is spirally rolled, though not prehensile. It now forms the genus PARADOXURUS of F. Cuvier, of which his brother the Baron admitted of only a single species (the animal just alluded to), under the name of *P. typus*, shown in Plate VI., figure 1. It is called *Pougouné* in India. If, as is generally supposed, it is also synonymous with the *Musanga* of Java, then the following particulars, communicated by Dr Horsfield, will apply to both. The musanga is most abundant near villages in the vicinity of the larger forests. It constructs its nest in the fork of a branch, or the hollow of a tree, of dry leaves, small twigs, and grass, and sallies forth at night in search of eggs and chickens. It also robs gardens of various kinds of fruit, is particularly fond of pine-apples, and devours coffee-berries in such quantities as to be very destructive in plantations of that commodity.[3]

GENUS HERPESTES, Illiger. *Ichneumon*, Lacepede. Incisors $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{5-5}$; = 36. Body elongated, and low upon the legs. Head small and pointed. Eyes susceptible of being covered with a nictitating membrane. Ears short and rounded. Feet with five toes, armed with sharpish semi-retractile claws. Tail long and pointed. Anal pouch large, but simple.

This genus, according to Geoffroy,[4] contains nine species, of which four are from India or the Indian Archipelago, one from Madagascar, two from undetermined regions, one from the Cape, and one from the north-east of Africa. The last is the celebrated ichneumon (*Herpestes Pharaonis*, Desm.), so noted in the mythology of ancient Egypt. It is larger than a cat, and shaped like a marten, the fur composed of hairs ringed with brown and fawn colour. The paws and muzzle are black, and the tail terminates in a diverging tuft. The ichneumon, "presenting a lively image of a beneficent power perpetually engaged in the destruction of those noisome and dangerous reptiles which propagate with such terrible rapidity in hot and humid climates," was adored by the Egyptains. It still abounds in the northern parts of the country, that is, between the

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[1] It is the *Hyæna picta* of Temminck, and the *Canis pictus* of Desm. See also the 2d volume of Burchell's *Travels*, and Griffith's *Animal Kingdom*, vol. ii. p. 376.

[2] *Synopsis of Mammalia*, p. 151. One of its previous *specific* names ought assuredly to have been retained.

[3] Some uncertainty seems to prevail in regard to the affinities which exist between the Bentourong of Raffles (ICTIDES?), and the genus above named.

[4] *Description de l'Egypte*, Hist. Nat. t. ii. p. 140.

Mediterranean and Siout, but it is rare in Upper Egypt. It preys on rats, reptiles, and the eggs both of birds and crocodiles, and is itself attacked by foxes, jackals, and the animal called Tupinambis. It is not bred in confinement by the modern Egyptians (who call it *Nems*), but being easily domesticated when taken young, and of kindly docile habits, it is often brought up as a kind of pet about their houses. Like cats, these animals acquire a strong attachment to particular dwellings, and readily recognise the voice and person of their master.

The Indian species, commonly called the *mangouste* (*H. mungos*, Desm.), is less in size than the preceding, its colour paler and more grey, and its tail pointed. It is celebrated, like its brother of the Nile, for its destruction of poisonous snakes and other reptiles, and is still more deservedly renowned for its strange instinctive discovery of the medicinal virtues of the plant called *Ophiorhiza mungos*, as an antidote to the otherwise fatal effects of their envenomed fangs. Another nearly allied species is the *Ichneumon griseus* of Desmarest (*Viverra cafra*, Gmelin). It is easily domesticated, and thrives well on bread and milk. Yet its carnivorous propensities are unsubduable, and it cannot be trusted in the vicinity of caged birds or poultry. It may be rendered useful in the destruction of rats and other vermin. This animal is said to occur both in India and the south of Africa. To it M. Geoffroy has (we think erroneously) applied the name of mangouste *nems*, thus bestowing an Egyptian name upon a species which assuredly occurs not in the country of the Pharaohs.

GENUS RYZÆNA, Illiger. *Surikata*, Desm. Incisives, $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; = 40. Four toes on both the anterior and posterior extremities.

This genus is constituted by the Surikate alone (*Viverra tetradactyla*, Linn.), an animal from the south of Africa, of a nature intermediate between the pole-cats and ichneumons. It is easily tamed, and, like a cat, becomes attached to its own dwelling. Buffon erred in deeming it a native of America.

We shall terminate this subdivision of the Digitigrada by the notice of a singular animal from the southern parts of Africa, which conducts us naturally to the hyenas. We allude to the *Proteles Lalandii* of Isidore G. St Hilaire,[1] formerly regarded as a genet, and named provisionally *Viverra hyænoides* by Baron Cuvier. It was originally transmitted from the Cape by M. Delalande, and belongs undoubtedly to a distinct genus. Its cranium partakes of the characters of the dogs and civets, and, like the canine tribes, it bears a fifth or rudimentary toe upon the fore feet; but its raised shoulders, sloping back, and all its outer aspect, are precisely those of a hyena, even to the radiated markings of the fur. It is a nocturnal animal, an inhabitant of the banks of the Fish River in Caffraria, and is supposed to have been examined as yet only in an immature condition. Its teeth amount to thirty, of which four are canine, twelve incisives, with eight molars in the upper jaw, and six in the under; but there is reason to believe that our knowledge of its true condition is as yet imperfect. (See Plate VI., figures 2 and 2 *a*.)

3D SUBDIVISION.

No tuberculous tooth behind the large carnivorous cheek-tooth of the lower jaw.

This subdivision consists of the most bloodthirsty and carnivorous of the class, and contains the Linnæan genus *Felis*, with the addition of the hyænas, which the great Swedish naturalist placed in the same genus as the dogs and wolves.

GENUS HYÆNA, Storr, Cuv. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{4-4}$; = 34. All the extremities with four toes. There are three false molars above, and four below, all conical, blunt, and singularly large; the upper carnivorous cheek-tooth has a small tubercle within anteriorly, but the inferior presents only a couple of strong cutting points.

The great size of the teeth in this genus, combined with the extraordinary strength of the muscles of the jaws and neck, bestow upon it a tremendous power of mastication, by means of which the species can crush to atoms the bones of the largest and most obdurate prey. Their hold is indeed so strong, and so tenacious, that it is almost impossible to wrest any thing from them when once enclosed within their iron fangs. Hence, among the Arabians, their very name is used as the symbol of obstinacy. Hyænas generally inhabit caverns and other rocky places, from whence they issue under cover of the night to prowl for food. They are gregarious, not so much we think from any social principle, as from a gluttonous and grasping instinct, which induces many to assemble together even over the most insufficient meal. They are accused of violating the sepulchres of the dead, for the sake of devouring whatever bodies they can disinter, or may chance to find but hastily inhumed. From such notions, however slightly founded, we usually associate a peculiar gloominess and malignity of disposition with the aspect of these creatures, and the name of "laughing hyena," which one of them bears, seems to render their character still more unnatural and revolting. We fancy them indulging in their horrid mirth, like reckless resurrectionists,—their hilarity increasing as they tear the protecting cerements from the dead man's grave. Like any other animal, however, the hyæna is perfectly capable of being tamed, and indeed a contradictory feature in regard to diet has been observed even in the manifestation of its natural and unbiassed instincts. About Mount Libanus, Syria, the north of Asia, and the vicinity of Algiers, the hyænas, according to Bruce, live mostly upon large and succulent bulbous roots, especially those of Fritillarias, &c.; and he informs us that he has known large patches of the fields turned up by them in their search for onions and other plants. He adds, that these were chosen with such care, that after having been peeled, if any small decayed spot became perceptible, they were left uneaten. In Abyssinia, however, and many other countries, their habits are certainly exclusively, or, at least, decidedly carnivorous, although the same courage or rather fierceness which an animal diet usually produces does not so obviously manifest itself. In Barbary, according to the same authority, the Moors, in the daytime, will seize the hyæna by the ears and drag him along, without his resenting such ignominious treatment otherwise than by attempting to draw himself back; and the hunters, when his cave is large enough to give them entrance, take a torch in their hands, and advancing straight towards him, pretend to produce fascination by the utterance of some senseless jargon. The creature in the mean time becomes so astounded by the unaccustomed noise and lurid glare, that he allows a blanket to be cast over him, and unresistingly succumbs to fate. Bruce one day locked up a goat, a kid, and a lamb, with a Barbary hyæna which had fasted, and in the evening he found the intended victims not only alive but quite uninjured. He repeated the experiment, however, on another occasion, during the night, with a young ass, a goat, and a fox, and next morning he was not unreasonably astonished to find the whole of them not only killed, but actually eaten, with the exception of some of the ass's bones! This was pretty well for an animal so curious in bulbous roots. Yet the experience of the narrator was undoubtedly great. "I do not think," says the Abyssinian traveller, "there is any one that hath hitherto written of this animal who ever saw the thousandth part of them that I have. They were a plague in Abyssinia in every situation, both in the city and the field, and I think surpassed the sheep in number. Gondar was full of them from the time it turned dark till the dawn of day, seeking the different pieces of slaughtered carcasses which this cruel and unclean people expose in the streets without burial, and who firmly believe that these animals are Falasha from the neighbouring mountains, transformed by magic, and come down to eat human flesh in the dark in safety." On entering his tent one night he perceived two large blue eyes glaring at him from the head of his bed. It was a hyæna with several bunches of candles in its mouth, but which immediately paid for its temerity as a tallow-chandler with its life.

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[1] *Mem. du Mus.*, t. xi. pl. 20.

Africa is the true country of hyænas, although the striped species (*Hyæna vulgaris*, Desm., *Canis hyæna*, Linn.) extends into western Asia. The spotted or Cape hyæna (*H. capensis*, Desm., *Canis crocuta*, Linn.) resembles the species just named except in the external markings of the fur. It carries the posterior part of the body very low, owing to the articulations of the hind legs being constantly bent. It is apt to feel dazzled by strong light, which gives an appearance of indecision to its movements during the day. It is easily tamed, and, according to Sir John Barrow, is trained in the district of Schneuburg for the service of the chace. The third species (which we here figure as an example of the genus, see Plate VI., figure 4) is called the brown hyæna (*H. brunnea*, Thunberg,[1] *H. villosa*, Smith).[2] It is likewise a native of Southern Africa, and is characterized by the blackish rays upon its legs.[3]

Genus Felis, Linn. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{4-4}{3-3}$ or $\frac{3-3}{3-3}$; $= 30$ or 28. Of the four molars of the upper jaw two are conical or false molars, one is a very large three-lobed carnivorous cheek-tooth, and the fourth (wanting in some of the species) is a small tuberculous tooth, broader than long. The molars of the under jaw consist of two simple compressed false molars, and one bicuspidate carnivorous cheek-tooth. There is no tuberculous tooth in this jaw, but its functions are performed by the inner lobe of the cheek-tooth, the rounded point of which, when the jaws are closed, is brought into contact with the flattened surface of the upper tubercular grinder. Head and muzzle short. Anterior feet with five toes, the posterior with four, all strongly armed with sharp, curved, retractile talons, held backwards in repose. Tongue rough, with horny papillæ pointing backwards.

The feline race, containing the most bloodthirsty and ferocious of animals, is characterized by an organic structure admirably adapted to the wants and habits of its numerous species. These differ greatly in size and colour, but resemble each other in shape and general proportions. The genus is distributed over the whole world, with the exception of Australia and the polar circles.

In a state of nature animals of the cat kind are almost continually in action both by night and day. They either walk, creep, or advance rapidly by prodigious bounds, but they seldom *run*, owing, it is believed, to the extreme flexibility of their limbs and vertebral column, which do not preserve the rigidity suitable to that species of progression. Their sense of sight, especially during twilight, is acute, their hearing very perfect, their perception of smell less so than among the canine race. Their most obtuse sense is supposed to be that of taste;—the lingual nerve in the lion, according to Desmoulins, being no larger than that of a middle-sized dog. The tongue of these animals is in truth almost as much an organ of mastication as of taste, the sharp and callous points with which it is covered being used for tearing away the softer parts of the animal substances on which they prey. The perception of touch is said to reside in great perfection in the small bulbs at the base of the whiskers.

We have elsewhere stated our opinion, that all that has been said regarding the noble generosity and superior courage of the lion and other species of the race, is considered by naturalists to be purely fabulous.[4] They seize their prey by surprise, lying in treacherous ambuscade, or gliding insidiously through dark ravines; and are constitutionally of a nature so shy and mistrustful, that if they fail in their first attempt upon the life of even an insignificant creature, they rarely renew it again upon the same individual. Neither does their ferocity by any means imply, as so frequently supposed, the fatal necessity of murder; for the instinct to destroy is only the sensation of hunger in animals having a propensity to flesh, and provided with the means of obtaining it. This instinct is itself effaceable by an artificial supply of food, provided continuously and in abundance. No existing animal (we mean of course of the higher classes,—inhabitants of the same element with ourselves) is rendered incapable, by the constitution of its nature, of being ameliorated by the art of man. The bloodthirsty jaguar of America plays with its keeper, as a kitten does with a child; and our menageries of recent years have exhibited many Bengal tigers of very mild and gentle manners.

The females are remarkable for their tender attachment to their young, while the males are distinguished by a peculiar jealousy, as it may be called, which frequently renders them the most formidable enemies of their own offspring. Hence it is, that the former sex usually conceal the places of their "procreant cradle," or frequently remove their young. They are, upon the whole, a solitary tribe (although young lions sometimes assemble together in small family groups), and, like most animals which feed on living prey, rarely seek each other's society except during the season of love. Like the "mighty hunters" among the human race, they require an extensive domain for the exercise of their predacious habits, and a near neighbour can therefore be regarded only as a mortal foe. It is the uneradicable nature of this sentiment which causes that peculiar noise in the throat and the mistrustful rolling of the eye, observable even in the most perfectly reclaimed individuals, when they are approached during meal-time. The cry varies greatly in the different species. The lion, when in that mood "of stern disdain at which the desert trembles," roars with a voice resembling distant thunder, deep, tremulous, and broken; the jaguar barks almost like a dog; the cry of the wily panther is like the grating of a saw; and most of them, when pleased, appear to *purr* after the manner of our domestic cat, with an energy proportioned to the size of the species.

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[1] *Mem. de l'Acad. de Stock.* 1820, part i. pl. 2.

[2] *Linn. Trans.* vol. xv. pl. 19.

[3] The *Canis* (*Hyæna*) *Hyænomelas* of Bruce is nothing more than a variety of the common striped species. The *H. venatica* of Burchell (*H. picta*, Tem.) has been already noticed under another head. The fossil species do not fall within the province of the present article.

[4] *Illustrations of Zoology*, vol. i. Genus Felis.

It would be inconsistent with the nature and prescribed extent of the present treatise to enter into descriptive details of the numerous and diversified species of which the genus Felis is composed.[1] The following notices must therefore be few and brief.

The lion (*Felis leo*) king of beasts, is easily distinguished by his uniform tawny hue, his large and flowing mane, and tufted tail. His general aspect is indeed strikingly bold and magnificent. His large and shaggy mane, surrounding his imperial front,—his bright commanding eyes, which upon the least excitement seem to glow with unearthly lustre,—his magnanimous and lofty countenance, symbolical of boldness from remote antiquity,—to say nothing of his muscular limbs, extensile talons, and the irresistible armature of his deadly jaws,—certainly embody our liveliest conceptions of warlike grandeur, and of a power not unbefitting his assumption of regal sway. The southern parts of Africa produce a variety of which the mane is nearly black. Those of Barbary are brown, with a very thick mane covering the neck and shoulders of the male. In Senegal they are of a yellow hue, with thinner manes. The Asiatic lion seldom attains to the dimensions of the South African kind, and his colour is paler and more uniform. Modern naturalists seem inclined to regard some of these animals as of different species, according to their natural localities, but they have as yet failed to point out satisfactory characters for their specific separation; and their general reasoning on the subject is rather hypothetical than conclusive.

The geographical distribution of the lion seems to have become greatly circumscribed within these last two thousand years, for from many districts where it formerly abounded it has now entirely disappeared. According to Herodotus it was once sufficiently common both in Thrace and Macedonia, and it is also known to have abounded in Asia, from the shores of Syria to the banks of the Ganges and the Oxus. The vast numbers brought together by the Romans during the games of the circus have been often recorded.

Inferior to the lion in the majesty of his deportment, but nearly equal in size and strength, and perhaps superior in activity, is the tiger (*Felis tigris*), a familiarly known, but greatly dreaded feline animal, of which the external characters need not to be here detailed. This "most beautiful and cruel beast of prey" has a more slender body, and a smaller and rounder head than his great congener. His motions, notwithstanding his vast deceptive bulk, are full of graceful ease and lightness; and the rich tawny yellow of the prevailing portion of his coat, contrasted with the numerous sloping lines of black, and the pure white of the under portions of his body, render him one of the most perfect pictures of savage beauty presented by the brute creation. The geographical distribution of this gorgeous tyrant of the East is much more extended (so far as Asia is concerned, for he does not occur in Africa) from south to north than that of the lion, as he not only advances far into those desert countries which separate China from Siberia, but is also found between the Irtysch and the Ischim, and even, though rarely, as far as the banks of the Obi. In a longitudinal direction, however, there is a much greater restriction of the one species than of the other, as the tiger appears but rarely to pass to the westward of a line drawn from the mouths of the Indus in a northerly direction to the shores of the Caspian Sea. The species was therefore much less familiarly known to ancient writers than the lion, and Megasthenes alone among the Greeks seems to have been acquainted with it from personal observation. Aristotle mentions it merely as an animal of which he had heard by name; and, even among the Romans, it was long regarded as of extreme rarity. Claudius exhibited four at one time, and it has been reasonably conjectured that the beautiful mosaic picture of four tigers, discovered a good many years ago in Rome, near the Arch of Gallienus, was executed in commemoration of so striking and unprecedented a display.[2]

The panther (*Felis pardus*, Linn.), the *pardalis* of ancient writers, is believed to occur over a great portion of Africa, the warmer parts of Asia, and the islands of the Indian Archipelago. It is usually marked along the sides with six or seven rows of black spots, each spot being itself composed of five or six small simple spots ranged in a circle. The leopard (*Felis leopardus*, Linn.) is a species closely allied to the preceding, but marked with ten rows of smaller spots, and believed to be confined to Africa. The hunting tiger or chittah (*Felis jubata*, Schreber), one of the most lively and elegant of the genus, is less than the panther, of a more slender form, and proportionally higher in the legs. Its toes are lengthened like those of a dog, and its claws, very slightly retractile, are blunter and less curved than in any other species of the cat kind. It is an Asiatic animal well known in eastern countries as an accessary in the chase of antelopes. The extent of its geographical distribution is still, we think, obscure. According to Thunberg it is common in the south of Africa,—a fact confirmed by Lichtenstein, who saw the chief of a horde of Caffres clothed in its beautiful and sumptuous skins; Temminck has ascertained its existence along the western shores of that division of the world; and several specimens have been lately transmitted from Nubia by Ruppel to the Frankfort Museum. Now the range is so great from the north of Africa to the far forests of Sumatra, where hunting tigers likewise abound, that observers have surmised that two species have been probably confounded under one name. Those from eastern countries are said to be more dog-like, to have longer legs, and a scantier mane. The chittah is known in Persia by the name of *youze*, and naturalists are of opinion that many of the skins received by furriers from Senegal and other parts of Africa, are identical with those of the hunting tiger of Hindostan. Many other feline species occur in Asia, Africa, and the eastern islands.

In the New World animals of this genus are likewise very numerous. Of these one of the most noted is the great panther of the furriers, *tigre d'Amerique* of the French, commonly called the jaguar (*Felis onca*, Linn.). It is a fierce and dangerous species, of which the habits have been well described by Humboldt, Azara, and other writers. Its general colour and aspect resemble those of the preceding spotted species, but it is of greater size, proportionably lower on the legs, with a larger head, and the circular spots, ranged along the sides in four rows, have usually each a smaller spot in the centre. The jaguar inhabits the forests which skirt the magnificent rivers of South America, and is by far the most formidable animal of the New World, where it is held in great dread by the native tribes, who are impressed with the belief that it prefers their flesh to that of white men. They are probably what the Highland schoolmaster would call more accessible, being less incumbered with clothing. While travelling, they light great fires during the night, from the notion (we believe well founded), that most wild animals fear the restless glare of that fierce element; yet, of six men stated by Azara as having been devoured by jaguars, two were carried away from the immediate precincts of a blazing fire at which they bivouacked. This animal so greatly abounded in Paraguay before the expulsion of the Jesuits, that 2000 are known to have been slain in a single year. Humboldt mentions, about the same period, that more than 4000 jaguars were killed annually throughout the Spanish colonies, and that 2000 skins were formerly exported every year from Buenos Ayres alone. No wonder that a cheerful fire, amid the damp recesses of the forests, should be there found less pleasant than in colder climes.

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[1] Most of these may be found in two works very accessible to all classes of readers,—the *Naturalist's Library*, edited by Sir W. Jardine (Mammalia, vol. ii.), and the *Miscellany of Natural History*, edited by Sir T D. Lauder (vol. ii. Feline Species). See also Griffith's *Animal Kingdom*, vol. ii, Desmarest's *Mammalogie*, p. 216, Temminck's *Monographie de Mammalogie*, t. i. p. 73, the Atlas to Ruppell's *Reise im Nordlichen Africa*, Azara's *Voyage au Paraguay*, and his *Essai sur l'Hist. Nat. des Quadrupedes* of that country, and Wilson's *Illustrations of Zoology* as last referred to.

[2] See *Ossemens Fossiles*, t. iv. p. 415. We do not think it necessary to burden our pages with anecdotes of tiger-hunting, &c. as these are to be met with (more than enough) in so many accessible volumes.

Another fierce, but less powerful species of the New World, is the puma or American lion (*Felis concolor*, Linn.). It is almost the only animal against which the charge of wanton or unnecessary cruelty seems well founded. It has been known to kill fifty sheep at one time, for the sake of sipping a little of the blood of each. Its manners differ considerably from those of the jaguar. It rather inhabits plains than forests, and approaches nearer to the habitations of man. In ascending a tree it is said to spring up at a single leap, and to descend in the same manner; while the jaguar runs up exactly like a common cat. Notwithstanding its ferocity in a state of nature, it is easily tamed when taken young, as we have elsewhere recorded of the specimen brought home in the Diamond frigate, by the late lamented Captain Lord Napier. The puma is more widely distributed than the preceding species, as it occurs not only over a great portion of South America, but extends northwards to the province of Pennsylvania, and even makes occasional inroads into the state of New York. For the history of the beautiful ocelot (*Felis pardalis*, Linn.), and of the other species of the New World, we must refer the reader to the works mentioned in the preceding note. In illustration of the genus, we have figured (see Plate VI., figure 3), the female of the chati (*Felis mitis*, F. Cuvier), a rare species, from South America. We have also represented[1] (see same plate, figure 6) another small species sent from India to the Edinburgh Museum. It exhibits an alliance to the lynxes in its slightly tufted ears.

In regard to the European feline animals, the only indigenous species (exclusive of the lynxes) is the common wild cat (*Felis catus*, Linn.), usually, though perhaps erroneously, regarded as the source of our domestic kind. A few lines may not be misbestowed on the subject of this curious inquiry. The opinion generally current amongst us, and even adopted by most naturalists, as to the origin of that useful domestic animal which we find as a reclaimed captive wherever man is in any measure civilized and gregarious, is, that it has sprung from the larger inhabitant of our rocky ravines and forests, a species of a brownish grey colour, paler beneath, marked with some deeper transverse bands, and three bars upon the tail, of which the lower part is blackish. Now several circumstances seem at variance with this supposition. The tail of the domestic cat is longer and tapers to a point,—that of the wild cat being of nearly equal thickness throughout, and thus appearing as if truncated at the extremity. The head, too, in the former is larger in proportion to the body.[2] All our other domestic creatures are larger than their original races, but the house-cat, supposing it to have sprung from the indigenous woodland species, seems to have reversed the rule; for never even its most pampered and overgrown condition does it in anyway equal the powerful dimensions of its supposed original.

When we seek to ascertain the origin of any anciently domesticated species, the mind naturally reverts to periods of antiquity, and to the history of nations characterized by remote records. It was from within the sacred precincts of the temples of Isis, and under the reign of the Pharaohs or Egyptian kings, that the earliest rays of science dawned upon the nations. There the heroic Greeks "drew golden light," and from thence were distributed, by more or less direct gradations, the knowledge and civilization which, long waning at the primal source with feeble and uncertain gleam, have burned like an unconsuming fire amid those "barbarian lands" to which they were conveyed. Egypt, so remarkable in the early civilization of the human race, might reasonably be supposed even *a priori* to have furnished the primitive families of mankind with one or more of its domesticated animals; and in relation more particularly to the present subject, we know that of all the ancient nations of whom we possess records, the Egyptians were the most noted for their appreciation of the useful qualities of the cat. It was even embalmed in their temples, in common with the mystical body of the ibis, and we doubt not it must have become familiar to them from its beneficial qualities as a domestic species; for the reverential regard in which several animals were held in ancient days may be supposed to have sprung either from the beneficial influence which they exercised in the economy of nature, or the more direct benefits which they conferred in the domestic state. That the people in question derived their cats from an indigenous source is more than probable, especially as a wild Egyptian species (*Felis maniculata*, Tem.) bears, of all others, the closest resemblance to the domestic breed. At all events, it could scarcely be drawn from the wild cat of Europe, as that species, though widely distributed over all the wooded countries of the continent, and ranging through Russia into Siberia, and over a great range of Asiatic territory, is unknown on the banks of the Nile, and seems to hold its centre of dominion rather in the temperate than the warmer regions of the earth. Another argument against the derivation of our domestic cats from the indigenous woodland species, may be drawn from the extreme scarcity of the former in the early ages of our history. It is known that in the time of Hoel the Good, King of Wales, who died in the year 948, laws were enacted to preserve and establish the price of cats and other animals remarkable for being alike rare and useful, and forfeits were exacted from any one who should kill the cat that guarded the prince's granary. Now, these precautionary regulations would seem to indicate that our domestic cats were not originally natives of our island, but were introduced from some of the warmer countries of the east, and required for a time considerable care and attention to preserve the breed. This would scarcely have been necessary had the original stock been found prowling in every thicket and *corrie* of the country, which the wild cat undoubtedly was in those distant days. We therefore agree with M. Temminck and other naturalists who suppose that the gloved cat of Northern Africa (*F. maniculata*) is the more probable source of our domestic kind (see Plate VI., figure 5). Its proportions agree generally with those of the wild cat of Britain, but it is smaller by about one-third, and its tail is comparatively longer and more slender. The nature of its coat and the distribution of its colours resemble those of the female wild cat, although it is more of a yellowish ash colour,—a hue, we may observe, which prevails in the natural tinting of many of the quadrupeds of northern Africa.[3]

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[1] From *Naturalist's Library* (*Felinæ*), p. 232, pl. 25. It is figured in the work referred to as the *Felis ornata*, but it is described under the title of *Felis servalina*.

[2] Fleming's *British Animals*, p. 15.

[3] See Temminck's *Monographies*, p. 120, note, *Edinburgh Cabinet Library* (Nubia and Abyssinia, No. xii. p. 401), and Ruppel's work before referred to.

The last group of the feline genus of which we shall make mention includes the animals known under the name of *lynx*. They are chiefly characterized by the length of their fur, the comparative shortness of their tails, and their tufted ears. Their skins are of considerable value in commerce, and it appears that several species have been confounded by naturalists under the name of *Felis lynx*, Linn. The largest and most beautiful is sent to us from Asia by way of Russia. Its fur is of a reddish-grey colour, spotted with black. It equals a wolf in size, and is the *Felis cervaria* of Temminck. The lynx of the north of Europe (*Felis borealis*, Temm.) is of an ashy grey, varying to brown and hoary, the fur being extremely full. Naturalists are now inclined to recur to the opinion of Pennant, that the Canada lynx (*F. Canadensis*, Geoff.) and this species are identical. According to Sir J. Richardson, they are timid creatures, incapable of attacking any of the larger quadrupeds, but well armed for the capture of the American hare, on which they chiefly prey. They make a poor fight when surprised by a hunter on a tree; for though they spit like cats, and set up their hair in anger, they are easily killed by a blow on the back with a slender stick. They swim well, and will cross the arm of a lake two miles wide. Their flesh, which is white and tender, though rather flavourless, is eaten by the natives.

The lynx of temperate and southern Europe (*Felis lynx*, Temm.) has a red fur, spotted with brown. It has now almost disappeared from the more densely peopled portions of the continent. A specimen described by M. Bory St Vincent was, however, killed within eight leagues of Lisbon. It is rather frequent among the central and southern mountains of Spain, where it is said to attain a greater size and a more beautiful aspect than elsewhere. It is likewise well known in the Neapolitan dominions. We presume that this is the species which occurs in Germany, where, however, according to Tiedemann, it is now much rarer than of old. M. Schyntz informs us that it is by no means unusual in Switzerland. M. Delarbe mentions one that was killed in Auvergne in 1788, and Cuvier has recorded another destroyed at Barege, at a much later date. We are not aware that it exists at present in France, though it may no doubt still descend occasionally in search of prey from the more secure fastnesses of the Pyrenees. The south of Europe produces a distinct species of smaller size, described by Oken under the name of *Felis pardina*.

The caracal or Barbary lynx (*Felis caracal*, Linn., see Plate VI., figure 8), is a native of warmer and more southern climates than the preceding. It is a wild and savage animal, of a uniform wine red colour, about the height of a fox, but much more powerful. It has been known to attack and tear a hound in pieces. The caracal is probably the animal designated by the ancients under the name of lynx, as the species now distinguished by that title has never been found in those countries of which the lynx of the ancients was said to be a native. Pliny assigns Ethiopia as its original country, and according to Ovid,

> "Victa racemifero lyncas dedit *India* Baccho."

Several other species are described by naturalists. Of these we have here engraved the booted lynx of Bruce (*Felis caligata*, Temm., see Plate VI., figure 7), a wild animal extensively distributed over Africa, and also occurring, it is said, in Southern India.

TRIBE III.—AMPHIBIA.

The concluding tribe of the carnivorous Mammalia consists of the seals and morses. Their feet are so short, and so encompassed in the skin, as to render their terrestrial movements very awkward, but as the intervals of their toes are filled by membranes admirably adapted for natation, their swimming powers are nearly inexhaustible, and they pass the greater portion of their lives in water. The form of the body is elongated, the spine extremely flexible, the muscles very powerful, the fur short and close.

The genus PHOCA of Linnæus comprises a great amount, and a considerable diversity of species,—some of which, though still regarded as *seals*, are separated into minor genera by modern naturalists. The teeth differ considerably both in their nature and number, and when accurately ascertained and distinctly described, will no doubt aid the systematic observer in his arrangement of the species into natural groups. All the species agree in having five toes to both extremities. Those of the fore paws diminish in size from the what we may call the thumb to the exterior or little finger, while on the hind legs the lateral toes are the largest, and the others diminish towards the centre. The form of the head bears some resemblance to that of a dog, and in their natural cunning and intelligence, and their capacity of being tamed and instructed, they present a farther likeness to that sagacious creature. They prey chiefly on fish, and are extremely destructive to salmon and other migratory and gregarious species along our shores, in estuaries, and at the mouths of rivers. They seldom, however, ascend the fresh waters to any considerable distance from the sea, and the alleged occurrence of seals in remote Siberian rivers, and the inland waters of Lake Baikal, is a fact which requires confirmation.[1]

Although extensively distributed over the waters of the ocean, it is in high latitudes (whether northern or southern) that seals occur in greatest abundance,—such as inhabit tropical regions being as it were insulated from their kind, and occurring in less numerous assemblages. The species are so vaguely described by voyagers, and have been even as yet so indifferently characterized by naturalists, that their geographical boundaries are in no way well defined; but we may rest assured that those authors are in error who describe our northern kinds as occurring equally among the antarctic icebergs. All other animals have limits which they do not pass, and seals are doubtless subject to a corresponding restriction. For example, the gigantic species called the sea elephant (*Phoca proboscidea*, Desm.) is never found in the northern hemisphere, while such of the smaller southern species as have been examined, are found to differ from those of corresponding size, which are native to the European shores. In regard to the geographical distribution of marine amphibia, the views of Peron are deserving of consideration. He is of opinion that the species, in reference to their natural location, form three great geographical groups, of which two are northern (Atlantic and Pacific) and one southern, and that the species of each of these regions are proper to itself. He inclines to apply the same principles to the cetaceous tribes. In neither case, however, has he sufficiently considered the numerous species which occur in temperate and equatorial regions. A proper exposition of the species of the Mediterranean and the Euxine, and their comparison on the one hand with those of the north, and on the other with such as are known to occur in the enclosed waters of the Caspian, the Red Sea, the Persian Gulf, the Indian Ocean, and the frozen waters of the extreme south, would prove a subject of deep interest. It is indeed singular that animals so important in the scale of creation, whether we regard their great economic value to mankind, their position in the system of nature, or their peculiar organization and habits of life, should hitherto have attracted so superficial a notice on the part of naturalists.

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[1] See Krachenninikow's *Voyage en Sibérie et au Kamtschatka*, t. ii. p. 421.

In the *restricted* genus Phoca (Peron), the external ear is obsolete or rudimentary; the incisives are pointed, with simple edges; the toes possess a certain degree of motion, and the claws by which they are terminated are placed on the margin of the uniting membrane.

Our common seal (*Phoca vitulina*, Linn., see Plate VII., figure 1) possesses, in common with the little group of species with which it is associated (*Calocephalus*, F. Cuv.), six incisive teeth above, and four below. It varies greatly in colour, and sometimes attains the length of six feet. It is frequent along the northern European shores, and extends into very high latitudes. It is even said to occur in the Caspian Sea, and the great fresh water lakes of Russia and Siberia; but this assertion, as Baron Cuvier has remarked, requires to be confirmed by an exact comparison of species. Seals were formerly used as food, though their flesh is coarse and dark coloured. Their blood is blackish, and very abundant. At present they are slain chiefly on account of their skins and oil. Dean Monroe informs us, that on the banks of Lochegrenord, in Islay, they were formerly killed by means of trained dogs. They seem occasionally subject to epidemic diseases. About fifty years ago numerous carcasses were cast ashore in every bay in the north of Scotland, Orkney, and Shetland, and many were found in a sickly state at sea.[1]

Our other British species is called the great seal (*Phoca barbata*, Fabr.). It attains the length of ten or twelve feet, and seems almost confined with us to the western and northern isles, although it has been occasionally met with off the Fern Isles, and a specimen was shot some time ago near Stonehaven by the late Lord Cassilis. It spreads, however, far and wide along the icy arctic shores.

Of the antarctic species we may name the small nailed seal, *Phoca leptonyx* of Blainville (genus Stenorhinchus, F. Cuv.), to which the species brought home by Captain Weddell from the South Orkneys, and now in the Edinburgh Museum, seems nearly allied.[2] The head of the latter is very small, the neck greatly elongated. Its teeth are, incisors $\frac{4}{4}$, canines $\frac{1-1}{1-1}$, molars $\frac{5-5}{5-5}$; $= 32$. The last named teeth are sharp, compressed, trilobate.

One of the most noted of the southern seals is the monstrous species so often mentioned by Dampier, Anson, Cook, and other navigators, under the names of sea lion, sea elephant, &c. It is the *Phoca leonina*, Linn. *Ph. proboscidea* of Peron and Desmarest, and probably also the *Ph. Ansonii* of the last named author, for its synonyms are almost as numerous as its own oily herds. It constitutes the type of the modern genus Macrorhinus, distinguished by having four incisive teeth in the upper jaw, and only two in the under, the molars obtusely conical, and the muzzle in the form of a short moveable proboscis. The species are widely extended over the southern hemisphere, and furnish the English and American fisheries with an important article of commerce. The sea elephant above alluded to is the largest of the group, attaining sometimes to the length of 30 feet, and measuring from 15 to 18 feet in circumference. The lower canines are long and projecting, and the male during the rutting season is characterized by the full inflated condition of the muzzle. It inhabits many of the desert isles and sandy shores of the southern hemisphere. According to Peron it migrates every season, with a view to avoid the extremes of heat and cold, moving southwards in summer and northwards in winter. Its favourite food consists of cuttle fish, and it loves to repose itself amid the thick and tangled beds of *Laminaria gigantea*. It is probable that it also feeds on fuci, as a quantity of marine vegetation has been found in its interior, mingled with the bones of cephalopodous mollusca. These animals keep much at sea during the first four months of the year, after which they pay frequent visits to the land. They move with great ease and some celerity in the water, but their motions on shore are slow and awkward, and they are then easily slain, notwithstanding their great strength and gigantic size. Their dispositions are naturally mild, their habits indolent, and their general character much less wary and mistrustful than that of the smaller tribes of seals. They are thus easily approached by man, and fall a ready victim to the lance of their pursuers. One male has generally several females, and, during the season of love, dreadful conflicts take place with a view to the formation of a seraglio. A certain degree of domestic peace is established in the autumn. Gestation continues about nine months, and the females bring forth one or two young ones in June of the ensuing year. At this period they usually assemble together on sandy flats, at some little distance from the shore, and surrounded by the males. They give suck for two or three months; during which time they are said to reside entirely on shore. They then descend together to the sea, where, after a few weeks' refreshment, they recommence their contentious courtships.[3]

We cannot here enter into farther details regarding the seal tribe, and shall conclude by observing that the *Phoca monachus* of Gmelin, a well-known Mediterranean species, common among the islands of the Adriatic, and the shores of Greece, and probably the species best known to ancient writers, belongs to the genus Pelagius of F. Cuvier, characterized by four incisors both above and below,—the molars being like obtuse cones, with a slightly developed heel before and behind.

The preceding groups of amphibious mammalia agree in the absence or rudimentary state of the external ear. It is otherwise, however, with the remaining genus Otaria, Peron, which is distinguished by *external ears*, and by the singular character of having double cutting edges to the four intermediate incisors of the upper jaw, the external being small and simple. All the molars are simply conical; the toes of the fore paws are almost immoveable; and the swimming membrane is prolonged in advance of the toes of the hinder extremities. All the claws are flat and slender. To this genus belongs the maned seal (*Phoca jubata*, Gmel.), or sea lion of Steller, Pernetty, and some other authors. It grows to the size of from fifteen to twenty feet, and the neck of the male is clothed with hair longer and more frizzled than that of the rest of the body. The species is usually described as occurring at both extremities of the Pacific Ocean, but the individuals found along the Patagonian coast, at the Malouin Islands, and in the Straits of Magellan, will assuredly be found to differ specifically from those of Behring's Straits and other northern regions. Forster describes them as living in troops, the old males roaring like lions or enraged bulls, and, except during the breeding season, living together apart from the females. On the Magellanic shores, they couple in December and January, carry eleven months, and bring forth two young. Those of Kamtschatka, according to Steller,[4] are of analogous habits; but in each group there are only two or three females, instead of ten or a dozen, and each produces at a birth only a single young. The flesh is held in some esteem by the natives of the Aleutian Isles and other northern tribes.

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[1] Fleming's *British Animals*, p. 17.

[2] Consult Weddell's *Voyage to the South Pole*, and Lesson's *Manuel de Mammalogie*, p. 200.

[3] For ample details see Peron's *Voyage aux Terres Australes*, 2d Ed. t. iii. pp. 55–103, and the well known narratives of our own illustrious circumnavigators.

[4] *De Bestiis Marinis*, Mem. Acad. Petersb., t. ii.

To the preceding genus also belongs the Sea Bear, so called (*Phoca Ursina*, Gmel.). It measures about eight feet, and is destitute of mane. The colour varies with age and season, from brown to grey and white. The young, when newly born, are black. The fur of this species, when cleared of the longer coarser hair, is almost as much esteemed as that of the beaver. It fears the maned seal, but wages a cruel war against most other marine creatures. A corresponding species exists in either hemisphere, that is, the Ursine Seal is described by Steller as a native of Kamtschatka, and by Foster as inhabiting the southern coast of America, and the shores of New Holland, and Van Diemen's Land. It is probable that two distinct kinds are here confounded.[1] Various additional species are described by MM. Desmarest, F. Cuvier, Lesson, and other systematic writers.

Genus Trichechus, Linn. Incisors $\frac{2}{0}$, canines $\frac{1-1}{0-0}$, molars $\frac{5-5}{5-5}$; $=24$. Body elongated, and conical, like that of the preceding groups of seals. Head round, muzzle full. No external ears. Tail extremely short.

The absence of canine and incisive teeth from the lower jaw sufficiently distinguishes the present genus, which as yet contains but a single species, commonly called the morse, walrus, or sea-horse,—*Trichechus rosmarus*, Linn. See Plate VII., figure 2. It attains to the length of from 18 to 20 feet, and in its general aspect and habits resembles a gigantic seal. It is an animal of gregarious disposition, and occurs abundantly in the Northern Atlantic, and the polar regions of the Pacific Ocean. The walrus is sought for amid those icy solitudes, on account of its oil, skin, and ivory tusks. The latter are harder and more homogeneous than those of the elephant, and are less apt to be rendered yellow by the hand of time, for which reason they are useful to dentists in the fabrication of false teeth. The capture of this animal is not, however, an object of such importance as it is known to have been prior to the institution of the Spitzbergen whale-fishery. In fact, it is now allowed to float along its desolate shores, almost without molestation from the British, the Russians being its principal persecutors. Our whale-fishers seldom take more than half a dozen in a voyage, although the elder Scoresby once procured in a single season 130 in Magdalene Bay. But this is nothing to the multitudes obtained in former times. Stephen Bennet, for example, in 1606, along the shores of Cherry Island, killed 700 or 800 in less than six hours; and in the ensuing voyage about 1000 were slain in less than seven hours. "When seen at a distance," says the Rev. Dr Scoresby, "the front part of the young walrus, without tusks, is not unlike the human face. As this animal is in the habit of raising its head above water, to look at ships, and other passing objects, it is not at all improbable but that it may have afforded foundation for some of the stories of mermaids. I have myself seen a sea-horse in such a position and under such circumstances, that it required little stretch of imagination to mistake it for a human being; so like indeed was it, that the surgeon of the ship actually reported to me his having seen a man with his head just appearing above the surface of the water."[2] The walrus is a fearless animal, paying no regard to a boat, except as an object of curiosity. Its capture in the water is not made without danger, as an attack on one individual generally draws its neighbours around it, and the planks of the boat are sometimes pierced with their tusks, which, from the great weight of the suspended body, become weapons of enormous power. The species is confined to the coldest regions of the northern hemisphere, and its southern boundary is probably more restricted than of old. It is mentioned by some of our ancient native writers, but has been long unknown along the British shores, although the ivory bits described by Strabo as articles of British commerce may be conjectured to have been fabricated from its teeth. In December 1817, a solitary wanderer, who had probably been floated southwards on an iceberg, was shot while reposing on a small rock in the Sound of Stockness, on the east coast of Harris, one of our Outer Hebrides.[3]

Order III.—MARSUPIALIA.

The order which contains the marsupial or pouched animals, is composed of such heterogeneous elements, as to be extremely difficult of definition. The most universal, as well as remarkable peculiarity, consists in the premature production of the young, the majority of which are born in a state comparable only to that exhibited by the fœtus of other animals not many days after conception. Thus the Virginian Opossum, when first brought forth, does not weigh above a single grain, though its parent is as large as a full-grown cat; and the Gigantic Kangaroo, which sometimes attains the weight of nearly 200 pounds, gives birth to a pair of young ones, each about an inch long. Incapable of voluntary movement, destitute of distinct sensation, and with the external organs in a rudimentary state, the feeble offspring becomes attached (in a manner as yet but indistinctly known) to the mammæ of the mother, and adheres to them continuously till such time as it has attained the ordinary conditions of a new born creature, and even long after that period it continues to seek frequent refuge in its parent's lap, which for that purpose is furnished with an ample pouch, within which the nipples are contained. Two special bones attached to the pubis, and interposed between the muscles of the abdomen, support the pouch, and occur at the same time not only in the females of certain species in which the pouch is scarcely perceptible, but also in the males, in which it does not exist.[4] Another peculiarity of the marsupial order consists in this, that in spite of a general resemblance which so strikingly pervades the species, that for a long time they were regarded as forming only a single undivided genus, they differ so greatly in their teeth, and in their organs of digestion and of locomotion, that a rigorous adherence to these characters, would induce their partition into various orders. "On disait, en un mot," says Baron Cuvier, "que les marsupiaux forment une classe distincte, parallèle à celle des quadrupèdes ordinaires et divisible en ordres semblables; en sorte que si on plaçait ces deux classes sur deux colonnes, les Sariques, les Dasyures, et les Peramèles seraient vis-à-vis des carnassiers insectivores à longues canines, tels que les tenrecs et les taupes; les Phalangers et les Potoroos, vis-à-vis des herissons et des Musaraignes; les Kanguroos proprement dits ne se laisseraient guère comparer à rien, mais les Phascolomes devraient aller vis-à-vis des rongeurs. Enfin, si l'on n'avait égard qu'aux os propres de la bourse, et si l'on regardait comme marsupiaux tous les animaux qui les possèdent, les ornithorinques et les echidnés

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[1] See, in addition to the works already quoted, the article *Phoque* of the *Diction. Classique d'Hist. Nat.*, t. xiii. p. 400.

[2] *Arctic Regions*, vol. i. p. 504.

[3] *Edinburgh Phil. Journ.*, vol. ii. p. 389.

[4] "La matrice des animaux de cette famille n'est point ouverte par un seul orifice dans le fond du vagin, mais elle communique avec ce canal par deux tubes latéraux en forme d'anse. Il parait que la naissance prématurée des petits tient à cette organization singulière. Les mâles ont le scrotum pendant en avant de la verge, au contraire des autres quadrupèdes, et la verge, dans l'état des repos, est dirigée en arrière." *Règne Animal*, t. i. p. 173.

Marsupialia.

y formeraient un groupe parallèle à celui des édentés."[1] In these views we can scarcely agree, and in truth they have not been proceeded upon by their author, who, in his most recent work, continued to group the marsupial genera under a distinct order, as above named.

Many years have elapsed since (in 1828) we ventured to express our opinion regarding the unnatural constitution of the marsupial order, and we are satisfied to see that similar sentiments have been generally expressed in more recent times. The present work does not present a proper field on which to enter into a minute detail of the many ingenious, though not always consistent, theories which have been proposed in explanation of the numerous anomalies observable in the structure and habits of this extraordinary assemblage of living creatures. Considered even in regard to their external structure, something remarkable may be presumed to characterize a group of animals regarding the division and arrangement of which scarcely two naturalists of note have expressed the same opinion. Baron Cuvier, as we have seen, made them constitute the fourth family of his Carnivorous Order; MM. Geoffroy St Hilaire and Latreille regarded them as forming of themselves a separate order, while M. De Blainville erected them into what he was pleased to call a sub-class of the animal kingdom. In fact, as we have already observed, the only principle on which zoological writers were formerly of one mind in relation to the Marsupialia, was that of holding the genera together in juxtaposition,—certainly an unfortunate principle to proceed upon, if it can be shewn to be inconsistent with the due consideration of those natural and undisputed analogies by which we profess ourselves to be guided in our arrangements of the other tribes. It has been well observed, that the marsupial genera exhibit the types of almost as many separate orders as exist among all the other Mammalia; and no one will doubt of this being in a great measure true, who has ever examined the well armed jaws of a Didelphis or Dasyurus, and compared them with the simple structure of the same parts in the gentle wombat.

According to the principles of the natural system so much (and deservedly) insisted on by the modern school, the group of genera named MARSUPIALIA, whether regarded as a family or an order, includes indeed such heterogeneous elements, as bid defiance to every preconceived form of classification. It is true that they all present some peculiar modifications of the generative and lacteal systems; and if the student has recourse to these alone, and regards them as a sufficient and satisfactory basis for the establishment of a primary character, in conformity with the nature of which the totality of the class Mammalia is to be partitioned into two great subdivisions, then the *Monodelphs* and *Didelphs* of M. De Blainville may suffice. But if the formation of a *class*, according to the admitted signification of the term, depends upon the coexistence of certain characters, neither few in number, nor of less than the highest value and importance in their kind, it is difficult to see why the mere existence of an external pouch, or duplication of the abdominal skin, though connected with a very peculiar, and it may be unaccountable mode of fœtal production, should suffice for the establishment of one of the greatest divisions of which the animal kingdom is regarded as susceptible. A bird differs in its class from a mammiferous animal or quadruped commonly so called, on the one hand, and from an amphibious animal or reptile on the other; and it is distinguished from both by many essential organic attributes, which involve such a difference in the vital functions and economy of the several subjects of these different classes, as to render their mutual discrimination, as it were, apparent to the most cursory observer. They not only differ in their mode of producing their young, and in their method of rearing it, but also in the structure of the heart, the character of the respiratory and circulating systems, the perfection of the senses, the number of the cervical vertebræ, and consequently in their whole external form and aspect. But the marsupial animals, however dissimilar to each other, do not vary essentially from certain types which occur in one or other of the numerous orders of which the *normal* mammalia are composed; and with these different genera they may assuredly be combined, in a manner more consistent with the principles of the natural system, than when they are allowed to constitute by themselves a separate and exclusive division, by whatever name it may be called. "Let each of the marsupial genera be classed according to the position pointed out by a careful study of its natural and most influential characters; and if, for example, the structure of its teeth indicate a carnivorous disposition in one genus, an insectivorous one in another, or a herbivorous one in a third, then let each be referred to its appropriate station in the general system, whether as a member of the Carnivora, the Insectivora, or in closer connection with the more harmless Glires. But do not re-establish the worst parts of an artificial method, by following a fanciful analogy in the structure of a secondary and apparently uninfluential organ. That the marsupium or pouch is not a character of a highly influential kind, is evident from its occurrence in tribes and genera which in every other respect are so variously and dissimilarly constituted. It does not, in short, afford a key to the rest of the organization."[2] The preceding observations may suffice to guard the reader from the supposition that the Cuvierian order of marsupial animals is of natural component parts We adhere, however, to that order, in conformity with our adoption of the general principles of classification laid down in the *Règne Animal.* The Marsupialia are arranged by Owen into five varieties, according to their digestive organs.

Marsupialia.

These tribes appear to be confined entirely to New Holland, America, and one or two islands in the eastern seas. They are unknown in Europe, Africa, and continental Asia. We shall now proceed to a brief notice of the genera.

DIVISION I. Long canines and small incisors in both jaws. Abdominal pouch sometimes wanting.

The hind molars of this group are beset with points, and in general all the characters of the teeth are those of the insectivorous tribes, to which they consequently approximate closely in their food and habits.

GENUS DIDELPHIS, Linn. Incisives $\frac{10}{8}$, canines $\frac{1-1}{1-1}$, molars $\frac{7-7}{7-7}$ or $\frac{6-6}{7-7}$; = 50 or 48. Head long and conical. Muzzle pointed. Mouth deeply cleft. Eyes placed high, oblique. Ears large, thin, nearly naked, rounded in their outlines. Tongue ciliated on the edges, and beset with horny papillæ. Five separate toes to each foot. The thumb of the hinder extremities (which are plantigrade) opposable, and destitute of nail; the nails of the other toes curved. Tail rather long, round, scaly, and without hair throughout the greater part of its extent. Stomach small and simple; cœcum of medium size, not pouched.

This genus contains the most anciently known of the marsupial tribes, and is peculiar to America, particularly the southern division. The species are known under the general name of opossums. They are nocturnal animals, resembling martens in their habits, but are less active in their movements. Their intelligence is limited, a fact in curious conformity with the entire absence of all folds or convolutions of the brain,[1] and according with the theory of M. Desmoulins, that the intellectual faculties are in the direct ratio of the extent of the cerebral surfaces.[2] They dwell in woods, where they climb the branches of trees, feeding on birds, eggs, reptiles, insects, and fruits. They enter farm-yards, and commit great damage by sucking the blood of poultry.

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[1] *Loc. cit.* p. 174.

[2] Wilson's *Illustrations of Zoology*, vol. i. Order Marsupialia.

One of the best known is the Virginian opossum, Plate VII., figure 3 (*Didel. Virginiana*, Penn.) It exists over a great extent of territory from Paraguay to the country of the Illinois, and is well known in the southern United States. This species lives in fields and woods, and often enters houses during the night, in search of domestic birds, or other prey. It brings forth upwards of a dozen young at a time, which at first do not weigh above a grain. They instinctively adhere to the teat, to which they continue fixed till they are as large as mice, and become covered with hair. The first gestation lasts about six-and-twenty days, and the offspring remain in the pouch for nearly twice that period. Azara has seen them carried along by their mother, by means of their little tails twisted round that of their parent.

The crab-eating opossum (*D. cancrivora*, Gmel.) is a more restricted species. (See Plate VII., figures 5 and 5 *a*.) It inhabits the coasts of Guiana and Brazil, and besides the usual prey, is said to feed greedily on crabs, which, according to Laborde, it catches by introducing its tail into their holes. Several other species are described by naturalists.

GENUS THYLACINUS, Temm. Distinguished from the preceding by the want of thumb on the hinder extremities, the tail covered with hair and not prehensile, and two incisors less in each jaw. The ears are of moderate size, and haired.

This genus has been instituted for the reception of a single species from Van Diemen's Land, described by Mr Harris, under the name of *Dasyurus cynocephalus*.[3] It is the *Thylacinus Harrisii* of Temminck.[4] This animal is as large as a wolf, though somewhat lower in the legs, and may be regarded as the strongest and largest of all the flesh-eating species of Australia. It is of a greyish colour, with transverse bands of black on the hinder parts of the body. The head is large, and resembles that of a dog. It dwells among rocks and caverns, in the deep and almost inaccessible glens in the vicinity of the highest mountains of its native island, and is said to prey upon the brush kangaroo and other quadrupeds. Some authors allege that it feeds on Ornithorhynchi, Echidnæ, and crabs, and that its compressed tail gives it great power and activity as a swimmer But we find nothing of this kind given by its original describer, who does not even mention it as a littoral species, although M. Temminck, and in his wake subsequent compilers, make it inhabit rocks by the sea shore. It may do so, but the fact is not stated by Mr Harris.

As we cannot detail the characters of all the minor marsupial groups, we may here note that the *Didelphis penicillata* of Dr Shaw, and the *Dasyurus minimus* of Geoffroy, form the genus PHASCOGALE of Temminck.

GENUS DASYURUS, Geoff. Incisives $\frac{8}{4}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; $= 42$. Anterior feet with five toes, armed with curved claws, the posterior with four, and a fifth in a rudimentary state, without nail, and distant from the others.

The Dasyuri approach the opossums (*Didelphis*) in their general organization, but wanting the strong thumb of the hinder extremities, and the tail being not prehensile, they are incapable of climbing trees like their American congeners. They prey chiefly during the night, feeding on small quadrupeds, birds, insects, mollusca, and the remains of seals or other marine animals which they may occasionally find along the shore. The species (at present four in number) are restricted to New Holland and Van Diemen's Land. We may mention as an example the *Das. ursinus* of Temminck (*Delph. ursina*, Harris), an animal of subterranean habits, extremely common at the time of our first settling at Hobart Town, where it proved particularly destructive to poultry. It, however, in return frequently furnished the convicts with a fresh dinner, and its flesh was said in taste to resemble veal. As the settlement increased they retired to the deeper recesses of the forest, where they are still easily procured by traps, baited with any kind of raw meat. Their tracks are often seen on the sea shore.

GENUS PERAMELES, Geoff. Incisors $\frac{10}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{7-7}{7-7}$; $= 48$. Head elongated, muzzle pointed. Feet with five toes, of which the fore paws have the innermost and outermost merely rudimentary, and without nails, and the middle toe the largest. The hind feet have the thumb or innermost toe rudimentary, and without nail, the second and third united under a common integument as far as the nails, the fourth the largest and most elongate, and the fifth or outer toe next in size to the preceding.

Although systematic writers describe three species of this genus, the only one as yet distinctly known is the long-nosed perameles (*P. nasuta*, Geoff.), or pouched badger of New Holland, an insectivorous animal resembling a large brown rat in its external aspect. (See Plate VII., figures 4, 4 *a*, and 4 *b*.) One of the most remarkable characters detected in a specimen submitted to our examination many years ago by Professor Jameson, consisted in this, that the marsupium, or abdominal pouch for the reception of the fœtal young, did not open from above downwards, as in most other marsupial animals, but commenced almost imperceptibly at the distance of half an inch from the anterior margin of the anus, and extended upwards beneath a thick fold of the skin as far as the sternum,—the entrance of the sack being arched upwards, and quite open for more than an inch from its lower or posterior margin. The whole cavity was lined with soft, very short, white, woolly hair, and its parietes were remarkably soft and dilatable.[5]

DIVISION II. Two long incisives in the lower jaw, projecting forwards. Six incisives in the upper jaw. The upper canines, as usual, long and pointed, but the lower so small as to be frequently hidden in the gums. Thumb of the hinder extremities separate and opposable, the two following toes shorter than the others, and united as far as the toes. The intestines and the cœcum long. An abdominal pouch in all the females.

The regime of this division, as might be inferred from the structure of the teeth and intestines, is almost entirely frugivorous.

GENUS PHALANGISTA, Cuv. The Phalangers properly so called, exhibit no extension of the skin along the flanks. They have in each jaw four posterior molars presenting a double range of points, besides a large anterior tooth compressed and conical, between which and the upper canine teeth are two others small and pointed. To the latter correspond the very small teeth of the under jaw already mentioned in the divisional character. The tail is prehensile.

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[1] See Tiedemann, *Icon. Cereb. Simiar. et quer. Mammal. rar.* tab. 5. fig. 9.

[2] See the article *Cérébro-spinal* of the *Diction. Classique d'Hist. Nat.* t. iii. p. 361.

[3] *Linn. Trans.* vol. ix. pl. 19.

[4] *Monog. de Mamm.* t. i. p. 60.

[5] See the detailed observations with which we were kindly furnished by Dr Grant (of the London University), and published in the first volume of our *Illustrations of Zoology*.

The species inhabit the Moluccas, New Holland, and Van Diemen's Land. They in some measure represent in the ancient world the opossums of America, but they differ greatly in their teeth. Those of the Moluccas and other eastern islands dwell in trees, and feed on fruits and insects. Their flesh is eaten, though it exhales a disagreeable odour. The tail is naked and scaly. M. Temminck distinguishes five species,—*Phal. ursina, chrysorrhos, maculata, cavifrons*, and *Quoy*. In the Australian species, the tail is furred. The latter amount to three,—*Phal. vulpina, Cookii*, and *nana*, Temm.[1]

In the genus PETAURUS of Shaw, which includes those animals commonly called flying Phalangers, the skin of the sides is more or less extended. By this structure they are partly supported in the air, so that their leaping powers are greatly increased. They are peculiar to New Holland. In some of the species, canine teeth still exist in the lower jaw, but extremely small in size. The upper canines, and the first three molars, both above and below, are very pointed. The posterior molars have each four points. As an example, we may name the pigmy opossum of Shaw (*Pet. pygmæa* of Desmarest, who of this group forms his subgenus of *Voltigeur* or *Acrabata*), one of the smallest of quadrupeds, scarcely exceeding a mouse in size. The hairs of the tail are beautifully disposed on either side, like the barbs of a quill. (See Plate VII., figures 7 and 7 *a*.) Other species want the lower canine teeth, and the upper ones are very diminutive. The four hinder molars also present four points, but somewhat curved or lunate, in which they approximate those of the ruminants. There are two additional anterior molars above and one below, of a less complicated character,—a structure which, as Cuvier observes, renders the species more frugivorous than the preceding.

DIVISION III. Two long projecting incisors in the lower jaw and six in the upper. Canine teeth in the upper jaw only. Hinder paws long and narrow, without thumb, the first two toes being very small, and united together as far as the base of the nails. An abdominal pouch in the females.

The only genus of this division is that called *Hypsiprymnus* by Illiger, consisting of the kangaroo rat, *Hyp. murinus*, Desm. (*Macropus minor*, Shaw). It has on each side of both jaws a long-shaped anterior molar, cutting and dentated, followed by four others beset by four blunt tubercles. There is only a single species known, of a mouse colour, equalling a small rabbit in size. Its regimen is herbivorous, its stomach large, divided into two sacks, and much pursed. The cœcum is rather small and rounded. This animal is called potoroo by the natives of New Holland.[2] The great length of its hinder extremities indicates its leaping powers.

DIVISION IV. No canine teeth in either jaw.

GENUS MACROPUS, Shaw, Cuv. *Halmaturus*, Illiger. *Kangurus*, Geoff. Desm. Incisives $\frac{6}{2}$, canine $\frac{0-0}{0-0}$, molars $\frac{5-5}{5-5}$; $= 28$. Extremities disproportioned, the fore legs being small, short, and furnished with five toes; the hinder legs, much lengthened, and muscular, with only four toes, of which the two inner are very small and united together. Tail lengthened, strong, furnished with powerful muscles, and of great use in locomotion. Hair woolly. An abdominal pouch in the female.

This singular genus, of which nearly a dozen species have been described by voyagers and systematic writers, contains the animals commonly called kangaroos. "Buffon, whose only errors were those of genius, clearly perceived that every continent, in its animal productions, presented the appearance of a special creation; but he gave an universality to this proposition, of which it is not altogether susceptible. It is nevertheless true, even at the present day, within certain limits. A great number of the Asiatic animals are not found in Africa, and *vice versa*. The lemurs seem to exist only in Madagascar. America is peopled with a host of mammalia exclusively peculiar to itself, and there are many more in Europe not to be found in the other quarters of the globe. The discovery of Australia has given an additional support to the opinion of Buffon. The species of animals there discovered have not only no affinity with those of the other continents, but, in fact, belong, for the most part, to genera altogether different. Such are those mammalia which the natives of New Holland call kangaroo, and which offer to the observation of the naturalist organic peculiarities perceivable in no other animal, with the exception of a single species. It is in this tribe that, for the first time, we view the singular phenomenon of an animal using its tail as a third hind leg in standing upright and in walking."[3]

Kangaroos in general dwell in small troops of from twelve to thirty, under the guidance of an old male. In a state of repose they rest as it were upon a kind of tripod, composed of the two hinder legs and tail, the body being nearly perpendicular, and the head extended horizontally. In moving leisurely they employ their fore feet like other quadrupeds, but, in more rapid progression, they advance by prodigious bounds, leaping, it is said, nearly thirty feet at a single spring. MM. Quoy and Gaymard, however, who often hunted these animals, inform us, "que lorsqu'ils etaient vivement poursuivis par les chiens, ils couraient toujours sur leurs quatre pieds, et n'executaient de grands sauts que quand ils rencontraient des obstacles à franchir." The support which they receive from their tails is also of great advantage in self-defence, by enabling them to inflict severe wounds with their hind feet. In the natural state their habits are herbivorous, but in a domestic condition they eat almost every kind of food. Their own flesh is held in considerable estimation, and as they now breed freely in this country, the time may come when we shall find a joint of kangaroo an acceptable and frequent dish upon our own tables. The females bring forth only one or two at a time.

One of the largest species of the genus is that described in Cook's first voyage. It is the *Macropus major* of Shaw (*Kangurus labiatus* of Desm.), and is distinguished by its fur of an ashy grey colour above, paler below, a transverse band of grey upon the chin, the upper surface of the legs and tail being of a blacker hue. It measures nearly six feet in height, and is well known in the neighbourhood of Botany Bay. Mr Cunningham probably alludes to the hunting of this species in the following passage:—"From the great length of their hind legs and tail, they are enabled to stand on the firm bottom, while the dogs are obliged to swim, and in this way a fight between a large kangaroo and a pack of dogs affords a most amusing spectacle. The kangaroo stands generally upright, with his fore paws spread out before him, wheeling round and round to ward off his assailants; and whenever one arrives within reach, he pounces his paws upon him, and, sousing him suddenly under, holds him fast in this position, gazing all the while around with the most solemn simpleton sort of aspect, heedless of the kicking and sprawling of his victim, whom he quickly puts an end to, if some courageous colleague does not in good time advance to aid, and force the kangaroo to let his half-drowned antagonist bob above water again, who paddles forthwith toward shore, shaking his ears and looking most piteously, with no inclination to venture in a second time, notwithstanding all the halloos and cheerings with which you urge him."[1]

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[1] The last named species is not inserted in the second edition of the *Règne Animal*, but another is described under the name of *Phal. Bougainvillii*. For the descriptions, see *Monograph. de Mammalogie*, p. 1.

[2] White's *Voyage to New South Wales*, p. 286. Philip's *Voyage to Botany Bay*, p. 277. M. F. Cuvier is of opinion that the observations of MM. Quoy and Gaymard have established the existence of other species besides the kangaroo-rat above named. To the latter they give the name of *H. Whitei*. It is probably identical with *Kangurus Gaimardi* of Desmarest.

[3] Griffith's *Animal Kingdom*, vol. iii. p. 47.

The preceding is sometimes confounded with a still larger species, called the sooty kangaroo (*K. géant* of F. Cuvier), which inhabits the south coast of New Holland, and is supposed likewise to occur in the vicinity of Port Jackson. The latter is seen in large troops, which, in the course of their habitual movements, form broad well-beaten footpaths, which a stranger would readily mistake for those occasioned by a numerous and active colony of the human race. Another species, called the banded kangaroo (*K. fasciatus*, Peron and Lesueu),[2] inhabits the islands (Bernier, &c.) on the west coast of New Holland. Its ears are smaller, and its tail feebler, than the same parts of the other species. It dwells among almost impenetrable thickets of a low growing species of mimosa, through which it forms numerous galleries, communicating with each other, and in which it seeks refuge on the approach of danger. From these and other peculiarities in its form and habits, M. Fred. Cuvier regards it as the type of a genus distinct from *Macropus*, and on which he bestows the name of *Halmaturus*, originally proposed by Illiger for the kangaroos.[3] We think it unnecessary to extend our observations on animals, the general habits of which have of late years been so frequently described, and shall merely name Le Brun's kangaroo (the Javan opossum of Pennant and Shaw, *K. Brunii*, Desm.) as a species which occurs somewhat beyond the range of its nearest allies. It inhabits the Aroe Islands, and, according to Le Brun, digs in the earth like a rabbit.[4]

Division V. Two long incisive teeth in the under jaw, no canines; two long incisives in the middle of the upper jaw, with some smaller lateral ones, and two small canines.

Here naturalists place only a single species, the *Phascolarctos fuscus* of Blainville, commonly called the *Koala*. Besides the teeth mentioned in the preceding divisional character, this animal has four molars on each side of both jaws, making twenty-eight teeth in all. Its feet are pentadactylous.[5] Its ears large and pointed, with the conch directed forward. The limbs are short, and the tail wanting. It somewhat resembles a bear in its aspect, and is said both to climb trees with facility and to burrow in the ground. The female carries about her young for a long time upon her back. The koala attains the dimensions of a middle-sized dog, and inhabits the banks of the river Vapaum in New Holland.

Division VI. Two cylindrical truncated incisives in each jaw. No canines.

This division, like the preceding, contains only a single species commonly called the Wombat, which constitutes the genus *Phascolomys* of Geoffroy and Cuvier. In addition to the teeth above mentioned, there are five molars in each side of both jaws, or twenty-four teeth in all. The wombat is about the size of a badger, and, in its general aspect, resembles a small bear. In its dentition and intestines it is closely allied to the order Rodentia, which we are now about to enter; but the articulation of the lower jaw is different. Its habits, however, are herbivorous. Captain Baudin introduced two specimens into the French Menagerie from the south coast of New Holland. Their motions were slow, their dispositions gentle and passive; and though tame, so far as the absence of fear was concerned, they exhibited little sense or discrimination. In their natural state they live in burrows, and the female brings forth three or four young at a birth. Peron stated that the flesh of the wombat is much esteemed by the seal-fishers, and Cuvier expressed his desire that it should be naturalized in the *basse-cours* of France, as likely to prove a valuable addition to the table. It is the *Phasc. wombat* (see Plate VII., figure 6) of Peron and Lesueur,[6] the *Phasc. Bassii* of Lesson,[7] and the *Wombatus fossor* of Geoffroy.[8] Some confusion has arisen in its history in consequence of Bass (and we believe also Flinders) having described under the name of wombat, an animal of corresponding external aspect, but furnished with six incisives, two canines, and sixteen molars in each jaw. The latter has by some been referred to the genus *Phascolarctos*, with which, however, its dentition is equally discordant. We know, in truth, little of the animals (whether of one or more species) hitherto recorded under the title of wombat, except that they are feeble defenceless creatures, inhabiting certain islands in Bass's Straits.[9] They seem to have been first noticed by Dr Shaw, in his crude compendium, under the name of *ursine opossum*,[10] and a good deal has been since written about them to very little purpose. Mr Bennet, however, informs us, that a wombat was kept alive, and in a tame state, at Been, in the Jumal country. It usually remained in its habitation till dark, and then came out in search of the keelers or milk vessels, from which it would contrive to get off the covers, and would then bathe itself in the milk, drinking at the same time. It would also enter the little vegetable garden attached to the station, in search of lettuces, to which it evinced great partiality; and when none could be found, it would gnaw the cabbage stalks without touching the leaves.[11]

Order IV.—GLIRES or RODENTIA. GNAWERS.

The following are the principal characters of this extensive order. Two large incisive teeth in each jaw, separated by an empty space from the molars. No canine teeth.

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[1] *Two Years in New South Wales*, vol. i. 314.

[2] *Voyage aux Terres Australes*, i. 114.

[3] We fear he has bestowed this name of *Halmaturus* (ἅλμα, saltus, οὐρη, cauda) on the species which it least befits.

[4] *Voyage aux Indes*, p. 374, pl. 213. See also Gould's *Mammals of Australia*.

[5] In relation to this character authors differ. "Le pouce manque au pieds de derrière," Cuv. *Règne Animal*, t. i. p. 188. "Le pouce des extrèmités postèrieures très gros, separé, sans ongle," Desm. *Mammalogie*, p. 276. We have never ourselves seen a koala.

[6] *Voyage aux Terres Australes*, pl. 58.

[7] *Manuel des Mamm.* p. 229.

[8] *Ann. Mus.* t. ii. p. 364.

[9] Naturalists differ even in their simple observation of the form of the intestines. The cœcum, according to Geoffroy, is very small and slender, while Cuvier describes it "gros et court." It is furnished with an *appendix vermiformis*.

[10] *General Zoology*, vol. i. p. 504. Its anatomy described by Sir E. Home in *Phil. Trans.*

[11] *Wanderings*, vol. i. p. 330.

Molar teeth either with flat crowns, or with more or less of a tuberculated surface. The four extremities terminated by unguiculated toes, which vary in number according to the species. Thumb sometimes rudimentary or obsolete; never opposable to the other toes. Number of mammæ various. Orbits not separated from the temporal fossæ. Lower jaw articulated by a longitudinal condyle. Hinder extremities exceeding the anterior in length. Stomach simple; intestines very long; cœcum large, but sometimes wanting.[1]

The genera of this order confine themselves chiefly to a vegetable diet, by which we mean not only leguminous plants, but grain, grasses, fruit, nuts, and other productions of the earth. They derive their name of gnawers from their mode of eating, which consists in reducing their food by a continuous action of the front teeth, into very small particles, instead of tearing it like the carnivorous tribes, or grinding it by a lateral motion, like the ruminating ones. In the Rodentia, the lower jaw is so articulated as to admit, in addition to the vertical movement which must necessarily obtain in all the higher animals, of a motion backwards and forwards, but not lateral; and in fine adaptation to this structure, the raised plates of the molar teeth are placed transversely, so as to act in more direct opposition to the confined horizontal movement of the jaw, thus aiding the power of trituition. A few of the species (such, for example, as the earless marmot, *M. citillus*, Linn.), are somewhat carnivorously inclined, and in natural accordance with this propensity, their molar teeth are jagged, or more sharply tuberculated than in other genera. Several of the murine species may be said to be omnivorous, and have become colonized in many foreign regions, through the unintentional agency of man. Most of the hybernating quadrupeds belong to this order. The Rodentia seem to inhabit all parts of the known world, with the exception of the numerous islands which compose the different central archipelagoes of the South Seas, where they do not occur as aboriginal. They are creatures of a timid disposition,—their habits for the most part nocturnal.

DIVISION I. With clavicles.

GENUS SCIURUS. Linn. Cuv. Incisors $\frac{2}{2}$, canine $\frac{0-0}{0-0}$, molars $\frac{5-5}{4-4}$; $= 22$.[2] Anterior paws with four toes, furnished with curved compressed claws, thumb tubercular; posterior paws with five toes, which, as well as the tarsus, are elongated. Tail long, usually furnished with an ample fur of considerable length. Two pectoral and six ventral mammæ.

The species of this genus, commonly called Squirrels, are with few exceptions essentially arboreal in their habits, and pass their lives among the umbrageous branches of forest trees, where they construct a spherical nest, composed of twigs, leaves, and moss, intermingled occasionally with a portion of fur apparently plucked from their own bodies. Certain species, however, inhabit burrows at the base of trees. Squirrels are extensively distributed over the whole earth, with the exception of New Holland, where as yet none has been discovered. Buffon was in error when he supposed the species in general to be characteristic of the colder and temperate regions of the earth; for we now receive many fine kinds from the warmest countries of Asia, and the sultry forests of Africa are by no means unproductive of these agile tribes. The species, however, are much more abundant in North America than in Europe.

The distichous or divergent character of the fur upon the tail, and the absence or existence of cheek pouches, furnish characters by which the genus is divided into minor groups.

Of those with distichous tails, but unprovided with cheek pouches, our common squirrel (*Sciurus vulgaris*), affords a familiar example. This beautiful and active creature is widely dispersed over the cold and temperate zones of the ancient continent, and its external colour and aspect vary with the diversified climates under which it occurs. Several imaginary species have been described by travellers not conversant with the modifications which it undergoes. In Britain, France, and Southern Germany, the fur is always of a reddish-brown above, more or less lively according to the season, and of a pure white below. In the northern parts of Europe and Asia, it assumes a much grayer hue in winter, owing to the hairs becoming encircled with whitish rings. A black variety is described by Pallas and Gmelin as native to the rugged and mountainous regions which surround Lake Baikal; but it is more than probable that it will be found to constitute a distinct species. The common squirrel does not hybernate or become torpid during winter, but stores up in the trunk of a tree a supply of nuts, acorns, pine seeds, &c., to which it has recourse, when the ordinary supplies of the forest have fallen or been exhausted. Its graceful and varied postures, with its beautifully flowing tail, its sparkling eyes and tufted ears, its activity and cunning in a state of nature, and familiar petulance in confinement, are all too generally known to need description. It never breeds in captivity. The only other European species with which we are acquainted is the *Sciurus alpinus* of M. F. Cuvier, a native of the Alps and Pyrenees. In its general size and proportions it resembles the common kind, but its head is somewhat less. Its colour is deep brown, speckled with yellowish-white above, the under parts being pure white. The inner surface of the limbs is grey; the edges of the lips are white. A fulvous band separates the white and grey of the under parts from the brown of the upper. A male and female lived for a long time in the Menagerie of the French Museum, and the colours of their coat underwent no change, further than that the brown became somewhat blacker in winter, and that the tail, during the latter season, assumed a greyer aspect.[3] For the numerous foreign species we must refer the reader to the works of systematic authors. We have figured as an example of the genus, the *Sciurus cinereus* of America. (See Plate VIII., figure 1.)

The *flying squirrels* belong to the genus PTEROMYS of Cuvier, and are characterized by an extension of the lateral skin, which spreads out from the fore to the hind legs, and, by acting as a parachute, greatly aids them in the act of leaping. A species (*Sciurus volans*, Linn. *Pt. Sibiricus*, Desm.), occurs in Poland, Russia, and Siberia. It feeds chiefly on the young shoots of pine trees, and, according to Pallas, its excrements thus acquire so resinous a quality, that they burn with a pure bright flame. It springs from branch to branch and from tree to tree with the most surprising agility. It is not readily tamed, and bites severely when in a state of irritation. Another flying squirrel (*Pt. volucella*, Desm.), erroneously named *polatouche* by Buffon, from the Russian name *polatucka* (which applies to the preceding species), inhabits the United States. (See Plate VIII., figures 4 and 2.) It lives well in captivity; and it even appears that a pair bred at Malmaison in 1809. This animal is frequently brought alive to Europe. Several other species inhabit the Eastern Islands.[4]

GENUS CHEIROMYS. Cuv. Geoff. Incisors $\frac{2}{2}$, canine $\frac{0-0}{0-0}$, molars $\frac{4-4}{3-3}$; $= 18$. Five toes to all the feet,—those of the anterior extremities very long and slender. The hind feet resemble hands, and are furnished with a short opposable thumb. Two inguinal mammæ.

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[1] As in the dormice, Genus *Myoxis*.

[2] The fifth molar of the upper jaw seems to occur only in the young, and disappears in the adult state.

[3] See Desmarest's *Mammalogie*, p. 332, and the article *Ecureuil* of the *Diction. Class. d'Hist. Nat.* t. vi. p. 67.

[4] Horsfield's *Zoological Researches*, liv. 4 and 5.

This singular genus, regarding the true position of which in the system a great diversity of opinion exists among naturalists, contains only one species, the *aye-aye* of Madagascar or long-fingered Lemur of Shaw (*Lemur psylodactylus*, Schreber, *Sciurus Madagascariensis*, Gmelin). This animal is of the size of a hare, its colour brown mingled with yellow, its ears large and almost bare, its tail very long, and rather densely clothed with long blackish hair. (See Plate VIII., figures 3 and 6.) The aye-aye is slow in its movements, of timid disposition and nocturnal habits. It was discovered by Sonnerat on the eastern coast of Madagascar. Little is known of its natural history; but a pair, kept alive for some months by the French traveller, fed on boiled rice, in the eating of which they made use of their long fingers, pretty much in the way in which the Chinese employ their chop-sticks. In a state of freedom it is said to pick out larvæ and other insects from beneath the bark of trees. In its distinct orbits, the form of the hind feet, and other characters, it seems allied to the quadrumanous order (at the termination of which it is placed by M. Desmarest), but its teeth are those of the Rodential tribes.

GENUS ARCTOMYS, Gmel. *Mus*, Linn. Incisors $\frac{2}{2}$, canines $\frac{0-0}{0-0}$, molars $\frac{5-5}{5-5}$; $= 22$. Anterior paws with four fingers, and the rudiments of a thumb; posterior with five. Tail of medium length, or short.

The marmots are subterranean dwellers, living together gregariously, and subject to the torpid state in winter. Although they feed on roots and other vegetation, the somewhat pointed tubercles of the molar teeth indicate a departure from the strictly herbivorous character, and they are easily induced to eat both flesh and insects. They are usually extremely fat, prior to the assumption of the torpid state, and the epiploon is then furnished with numerous adipose leaflets; when they awake again on the return of spring, they are very thin, and their weight has become sensibly diminished, a proof that the fatty substance with which they are so amply furnished, supports the system not only in hybernation, but also during those trying periods when they are roused by any accidental alternation of temperature.[1] It is seldom, however, that they are exposed to sudden changes in those deep burrows, in which they take their winter sleep. The genus is at present composed of a great amount of species, the majority of which inhabit the temperate and colder regions of both continents. Above a dozen occur in North America, and (including the three species brought from Buckharia by M. Eversham), about eight are found in Europe.[2]

The most generally known species is the marmot of the Alps (*Arct. marmotta*, Gmel., *Mus alpinus*, Linn.), an animal somewhat larger than a rabbit, of a yellowish-grey colour, ashy towards the head, the upper part of which, and the end of the tail, are black. It inhabits high mountains immediately beneath the line of perpetual snow. Though of a stupid aspect, it is a creature not only of great instinctive intelligence, but also susceptible of education, while its habits, in a state of nature, are in every way worthy of attention. Several individuals combine in forming a subterranean retreat, contrived with great art, and consisting of an oval cavity or general receptacle, with a large canal or passage, divaricating so as to present a couple of outlets. These recesses are generally made on declivities, and are supplied during autumn with an ample store of moss and hay. During the joyous summer season the alpine marmots are often seen sporting near their holes, or sitting upright in the enjoyment of the genial sunshine; but it is said that a sentinel is usually placed on the summit of a neighbouring crag, to give warning of approaching danger. Certain it is that they are very wary, and not easily surprised at any distance from their subterranean retreats. When the increasing cold of autumn betokens the approach of their long continued winter sleep, they betake themselves to their chambers, which they have previously furnished with the sweet summer hay. With the same, or some similar material, they also close up the opening to their dwelling, and soon fall into a torpid state, which continues till the spring. When they first enter their winter quarters they are extremely fat, but become emaciated after the lapse of a few months. If carefully dug up they may be carried away without awakening; but the heat of a warm chamber speedily restores them to active life. In like manner, if well cared for in confinement, they do not assume the torpid state. From these, and other facts well known to naturalists, it would appear that hybernating animals are not condemned to torpidity by any inherent quality of their nature, but that it is rather a provisional faculty, dependent on external circumstances, and may consequently be interrupted, postponed, or altogether prevented, by regulating the conditions under which the individual is placed.[3] The Alpine marmot is less productive than most of its order. It brings forth only once a year, and produces four or five young at a birth. These increase rapidly, and are not only easy to tame, but may be taught to perform various tricks and gesticulations. In a domestic state they are almost omnivorous, and in eating they sit upright, and use their paws like a squirrel.

Another noted species is the *bobac* or Polish marmot (*Arctomys bobac*, Gmelin). It is found in Poland, in the basins of the Dnieper and Borysthenes, and spreads through the north of Asia into Kamtschatka. It lives in groups of from twenty to forty, digging deep excavations on the southern sides of hills of no great elevation, and resembles the preceding species in its general habits. The souslik or variegated marmot (*Arctomys citillus*, Gmel.) differs in not being gregarious. It is of a more irascible disposition, and exhibits a tendency to prey on animal food. In addition to the supply of hay, chiefly used for bedding by the other species, this kind stores up roots, nuts, grain, &c. from which its winter sleep may be inferred to be less profound. Pallas, indeed, informs us, that such as are occasionally found in granaries are observed in motion even during the winter season.[4] The so-called variegated or Siberian marmot has a widely extended distribution, occurring in Austria, Bohemia, and European Russia, and spreading northwards into Siberia, Kamtschatka, and the Aleutian islands, and southwards to Persia and Hindustan. The species of this genus are likewise numerous in North America;[5] of these, however, we shall here notice only the

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[1] Mangili's *Mémoire sur le Lethargie des Marmottes.*

[2] For the species see Pallas's *Nov. sp. Quadrup. e Glir. Ord.* and the *Fauna Boreali-Americana*, part i.

[3] See the article ANIMAL KINGDOM of this work, vol. iii. p. 180.

[4] It may be here noted, however, that under the title of *Mus citillus*, Pallas is supposed to have described three distinct species of marmot, two of which he regarded as varieties of the other. The actual distribution of each is therefore probably more circumscribed. See *Novæ species Quadrupedum e Glirium Ordine*; and for the recent species, *Voyage à Boukhara*, par M. le Baron Meyendorff, in 1820, in which the animals collected by M. Eversman are described by Lichtenstein.

[5] For the Marmots of the New World, see Godman's *American Natural History*, vol. ii., Dr Harlan's *Fauna Americana*, the *Travels* of Lewis and Clarke, and Sir J. Richardson's work already so frequently referred to.

Quebec marmot (*Arctomys empetra*, see Plate VIII., figures 5 and 8) of Pennant.[1] It inhabits woody districts, at least as far north as lat. 61°. Although it is a subterranean species, it also climbs trees and bushes, probably in search of buds or other vegetation. The natives capture it by pouring water into the hole which it inhabits. They consider its flesh as a delicacy when in good condition. Its fur, however, is of no value.

GENUS MYOXIS, Gmelin, *Mus*, Linn. Incisives $\frac{2}{2}$, canines $\frac{0-0}{0-0}$, molars $\frac{4-4}{4-4}$; $= 20$. No cheek pouches. Anterior paws with four toes and a rudimentary thumb; posterior with five. Tail long, sometimes round and bushy, sometimes depressed and distichous, occasionally tufted only at the extremity. Hair very fine and soft. No cœcum.

The beautiful species, commonly called *dormice*, which constitute this genus, seem characteristic of Europe. They resemble squirrels in many of their habits, live in woods, and store up provisions for their winter store, although they pass most of that season in torpidity.[2] Their food consists chiefly of nuts and fruits, but they are said to attack occasionally the eggs and young of small birds. They pair in spring, and bring forth usually about five young in summer. Many curious observations have been made upon the nature of their hybernal sleep by Mangili, Saissy, Edwards, and others. Respiration is suspended and renewed at regular intervals, which vary, however, with the temperature. Thus, at 3° an individual observed by Mangili respired twenty-four or twenty-five times consecutively in a minute, after four minutes of repose. Their bodily temperature also falls. A lerot or garden dormouse, which in summer shewed a heat of 36° 5′, exhibited in December only 21°. Edwards has shewn that hybernating animals habitually produce less heat than other warm-blooded species, and that in that respect they continue permanently under the same conditions as the young of ordinary animals.

The fat dormouse (*Myoxis glis*, see Plate VIII., figure 7) is the most nearly allied to the squirrels. It dwells in forests, climbs trees, and leaps from branch to branch with considerable agility. It builds its bed in hollow trees, or in rocky clefts, dislikes moisture, and rarely descends to the ground. It is confined to the warmer and temperate parts of Europe, and was used by the Romans (as it still is in Italy) as food. That luxurious people fattened it for the table in receptacles called *Gliraria;* and Martial was of opinion, that in spite of long continued abstinence it became fattened by its winter sleep:

> "Tota mihi dormitur hiems; et pinguior illo
> Tempore sum quo me nil nisi somnus alit."

The flavour of its flesh resembles that of the guinea-pig. The lerot or garden dormouse (*M. nitela*) is more numerous and widely spread than the preceding. It inhabits temperate Europe as far north as Poland, and frequently occurs in gardens and outhouses. It inhabits holes in walls and hollow trees, and is injurious from its habit of climbing espalier trees, and eating the best and ripest fruit, especially peaches. It is itself uneatable. The muscardine (our English dormouse, *Myoxus muscardinus*, Gmelin, *Mus avellanarius*, Linn.) is scarcely larger than a common mouse. It never enters houses, but inhabits woods, where it makes a nest like that of the squirrel, composed of interlaced herbage opening from above, and usually placed on a hazel bush, or some low growing tree. It hybernates in hollow trees, occurs over Europe from Italy to Sweden, and is the only British species. Although extremely lethargic it is easily roused from torpidity, by either a diminution or increase of temperature. M. Mangili exposed a dormouse in a lethargic state to an artificial cold of 10°, and it died in twenty minutes. When opened a great quantity of blood was found in the ventricles of the heart and in the principal vessels connected with the lungs, while the lungs themselves, as well as the veins of the neck, head, and brain, were much distended.

GENUS ECHIMYS, Geoff. Incisives $\frac{2}{2}$, canines $\frac{0-0}{0-0}$, molars $\frac{4-4}{4-4}$; $= 20$. No cheek pouches. Four toes and the vestige of a thumb on the anterior feet; the posterior with five toes. Tail long, scaly, slightly haired. Fur coarse, and intermingled with flattened spines.

This genus consists of several South American species usually designated *spiny rats*, although in some the hair is of the usual kind. We know little of their history or habits. The red species (*Ech. spinosus*) is described by Azara as digging burrows in dry and sandy soils, four or five feet long, about eight inches beneath the surface, and sometimes so numerous and close together, as to render precaution necessary on the part of the pedestrian. It measures about eight inches in length.

GENUS HYDROMYS, Geoff. Incisives $\frac{2}{2}$, molars $\frac{2-2}{2-2}$; $= 12$. Feet with five toes, the thumb almost enveloped in the skin, the anterior toes free, those of the hinder extremities connected by a swimming membrane. Tail nearly as long as the body, cylindrical, pointed at the extremity, and covered with coarse hair.

Two Australasian animals (*H. leucogaster and chrysogaster*, Geoff.[3]), by some regarded as varieties of each other, constitute this obscurely known genus. The yellow-bellied species was described from a single individual killed by a sailor on an island in the straits of Entrecasteaux, while it was endeavouring to hide itself beneath a heap of stones. (See Plate VIII., figures 9 and 12.) Its fur is softer and finer than that of the white-bellied species. Both kinds measure about a foot in length, besides the tail, which extends eleven inches. In the first edition of the *Règne Animal*, they were erroneously regarded as natives of Guiana, and their supposed attributes are still commingled with those of a South American animal of amphibious habits, called the *Coypou* (genus *Myopotamus* of Commerson). Setting aside, then, the generalities which apply to the latter animal, we believe that nothing is known of the habits of the Hydromys. They are, in the mean time, inferred to resemble those of our water rats.[4]

We shall here merely name the

GENUS CAPROMYS of Desmarest, which contains two species native to the island of Cuba, where they are known to have been used as food by the natives. They resemble enormous rats.[5]

GENUS MUS, Cuv. Desm. Incisives $\frac{2}{2}$, molars $\frac{3-3}{3-3}$;

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[1] *Arctic Zoology*, vol. i. p. 111. The Quebec marmot of Forster (*Phil. Trans.* lxii. p. 378), is, however, another species—the *Arctomys Parryi* of Richardson.

[2] The only exotic species with which we are acquainted (*M. Coupeii*, F. Cuvier, *M. murinus*, Desm., an animal imported from the Cape of Good Hope by Delalande), although probably in its native country active throughout the year, was found to become lethargic when exposed to the cold of Europe.

[3] *Ann. du Mus.* t. vi. pl. 36.

[4] *Diction. Class. d'Hist. Nat.* t. viii. p. 427.

[5] See *Mem. de la Soc. d'Hist. Nat. de Paris*, t. i. p. 43; and *Règne Animal*, t. i. p. 200.

= 16. Anterior feet with four toes and a rudimentary thumb, the posterior with five. Tail long, naked, and scaly.

This genus, still of great extent, is now restricted to the rats and mice properly so called, an omnivorous race, some of which have followed man throughout his almost universal migrations. Wherever European nations have colonized, these small but adventurous creatures have accompanied the merchant or the mariner; and from the forlorn settlements of the fur traders of North America to the populous cities of Southern Asia, their sly and furtive habits are the source of equal annoyance.

The common brown rat of this country (*M. decumanus*) is believed to be an eastern animal, a native of Persia and Hindustan, which made its appearance in the western countries of Europe only during the earlier half of last century. It is a bolder and more powerful species than its predecessor the black rat, which it is said to have nearly extirpated.[1] It burrows under the foundations of walls and houses, makes its way into drains of foul water, swims with great facility, abounds in sea-port towns, and frequently establishes itself on board of ship. It is extremely prolific. This species is now well known in America and the colonies. It was unknown, even in the maritime towns of France, prior to 1750; and according to Pallas, was unobserved in Siberia and Russia before 1766. About that period they were seen to arrive in great troops towards the embouchure of the Wolga, and in the towns of Astracan and Jaitzkoi-Gorodok, appearing to come from the western desert, that is, from the European side.

The black rat (*Mus rattus*) is a smaller animal, of a darker colour, a more elongated head, and sharper muzzle than the preceding. It is equally omnivorous, but less productive. Its original country is extremely doubtful. Ancient authors make no mention of it, and the prevailing belief is that it made its way into Europe during the middle ages. It is still the prevailing species in some parts of the continent, but is now comparatively rare in Britain. Dr Fleming, however, observes, that "the period of their extirpation is far distant. They still infest the older houses of London and Edinburgh, and in many districts of the country they are common."[2] It was observed during the great fires which occurred in the ancient quarter of the last named city in the year 1824, that such rats as were dislodged from garrets and other lofty places, were all of the black kind.

Foreign countries produce various species of the rat tribe unknown to Europe. Of these we shall briefly describe the Malabar rat of Dr Shaw,—*Mus giganteus* of General Hardwicke,—a species of enormous size.[3] The nose is rounded, the under jaw much shorter than the upper, the cutting teeth broad, incurved, compressed. The body is thick, and greatly arched, the upper portion black, the under inclining to grey. The legs and toes are black, and the tail, thinly covered with hair, measures two and a half inches in circumference at the root. The specimen just noticed was a female, and weighed two pounds eleven ounces and a half. The male weighs above three pounds, and, including the tail, which is above a foot long, measures nearly thirty inches in length. This huge rat is found in many places on the Coromandel coast, in Mysore, and in several parts of Bengal, between Calcutta and Hurdwar. It is partial to dry situations, and scarcely ever occurs at a distance from human dwellings. According to General Hardwicke, the lowest caste of Hindoos eat the flesh of this rat in preference to that of any other species. It is extremely mischievous, and will burrow to a great depth, passing beneath the foundations of stores and granaries, unless these are very deeply laid; and it perforates with ease the walls of such buildings as are formed of mud or unburnt bricks. It is also destructive in gardens, from its habit of turning up the seeds of all kinds of leguminous plants. Fruits likewise suffer from its depredations, and it will even attack poultry when at all stinted in its vegetable diet. The bite of this species is considered dangerous; and a European serving in the Honourable Company's artillery is known to have died in the Doub of confirmed hydrophobia, in consequence of having been bit by it. One of the largest and most destructive rats with which we are acquainted is the *pilori*, or musk-rat of the Antilles (*M. pilorides*, Pallas and Gmelin), which measures fifteen inches in length, exclusive of the tail.[4]

Several foreign rats (not to be confounded, however, with the genus *Echimys*, already noticed) have a portion of their hair so strong and stiff as to be almost spiny. Such is the Perchal rat (*Mus Perchal*, Shaw), a species which measures above a foot in length, exclusive of the tail. It inhabits houses in the town and neighbourhood of Pondicherry, where it serves as food. Another spiny species occurs in Egypt, and is described by Geoffroy under the name of *Mus Cahirinus*.

Of the smaller species, or mice, we need scarcely describe the external aspect. The common domestic species (*Mus musculus*) was well known to ancient writers, and now occurs in most countries of the known world. It is amazingly prolific, sometimes producing seventeen at a birth. Aristotle's experiment in relation to this point has been often quoted. He placed a pregnant female in a vessel of grain, and after the lapse of a short period he examined his store, and found the grain greatly diminished, but the mice increased to 120. To the same genus belongs a somewhat larger species, called the long-tailed field mouse (*M. sylvaticus*), which resembles the preceding in the colour of its upper parts, but has the sides more rufous, the ears larger, the head longer, and the eyes more prominent. It dwells in fields, woods, and gardens, stores up seeds and roots in autumn, and is said to become torpid in very cold weather. This species is extremely abundant in certain seasons, and is often very destructive in plantations, by gnawing asunder the seedling trees or devouring the seeds. Buffon was of opinion that it did more damage in these respects than all other quadrupeds and birds together. They are killed abroad by fastening a roasted walnut to a stick, the latter supporting a large stone. In this manner above 2000 have been killed between the 15th November and the 8th of December, in a piece of ground not exceeding forty French arpents. The harvest mouse of White (*M. messorius*) is the smallest of British quadrupeds, the length of its body measuring only about two inches and a quarter. It builds its nest above ground. The one described by Mr White was composed of the blades of wheat, was perfectly round in its form, of the size of a cricket ball, with an aperture so ingeniously contrived, as to be discovered with difficulty. It contained eight young ones, all blind and naked, and was suspended in the head of a thistle. It is also often hung amid the blades of standing corn. The harvest-mouse, like most of the field species, is more frequently met with in the autumn than during any other season. It seeks protection from the winter's cold in hay or corn ricks, or in burrows beneath the earth. We have ourselves found it several times in the neighbourhood of Edinburgh. It does not appear to have been as yet generally recognised on the continent of Europe, though well known in some of the provinces of France, where of late a still smaller species has been discovered, the *mulot nain*, *M. pumilus* of F. Cuvier.

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[1] We find the above observation recorded in all modern books of natural history,—Pennant's opinion having been followed by our English compilers; and the same sentiment prevails in most foreign works. "Il est vorace," says M. Desmarest, "fait la guerre la plus acharnée au rat noir," &c. *Mammalogie*, p. 299. Neverthless, we have sought in vain for the evidence on which such supposition has been founded. "On the contrary," says Dr Fleming, "I know that they have lived for years under the same roof, the brown rat chiefly residing in holes of the floor, the other chiefly in holes of the roof." *British Animals*, p. 20.

[2] Ibid.

[3] *Linn. Trans.* vol. vii. p. 306.

[4] *Règne Animal*, t. i. p. 201.

The American field-mouse (*Mus leucopus*, Rafinesque) inhabits the northern districts of the New World, and extends across the whole country from the shores of Hudson's Bay to the mouth of the Columbia. It becomes an inmate of the dwelling-houses as soon as any have been erected at a trading post. "The gait and prying actions of this little creature," says Sir J. Richardson, "when it ventures from its hole in the dusk of the evening, are so much like those of the English domestic mouse, that most of the European residents at Hudson's Bay have considered it to be the same animal, altogether overlooking the obvious differences of their tails and other peculiarities. The American field-mouse, however, has a habit of making hoards of grain or little pieces of fat, which I believe is unknown of the European domestic mouse; and what is most singular, these hoards are not formed in the animal's retreats, but generally in a shoe left at the bedside, the pocket of a coat, a nightcap, a bag hung against a wall, or some similar place."[1] This species may be regarded as the representative of the *Mus sylvaticus* of Europe. In the stoat or ermine it finds a most inveterate and deadly foe, being frequently pursued by that greedy bloodsucker even into the sleeping apartments of the settlers.

Genus Gerbillus, Desm. *Meriones*, Illig. Incisives $\frac{2}{2}$, molars $\frac{3-3}{3-3}$; $=16$. Anterior feet short, furnished with four toes, and a rudimentary thumb; the posterior long, with five toes. Tail long, and covered with hair.

The species of this genus are peculiar to the warmer portions of the ancient continent. They may be described as long-footed rats, allied in many respects to the gerboas, with which indeed they have been frequently confounded. As an example we may mention the *Mus tamaricinus* of Pallas, a subterranean animal, inhabiting the southern shores and deserts of the Caspian Sea. An Indian species (*G. Indicus*) was discovered by General Hardwicke;[2] and several others inhabit Africa, from Nubia to the Cape. They are great leapers.

Genus Meriones, F. Cuv. Separated from the preceding on account of the greater length of the hind legs, the nakedness of the tail, and the existence of a very small tooth in front of the molars of the upper jaw.

The species are American, and the best known is that called the jumping mouse of Canada, described as a gerboa by General Davies.[3] It is an animal of extreme agility, of the size of a mouse, with a very long tail. "The first I was so fortunate to catch," says the gentleman just named, "was taken in a large field near the falls of Montmorenci, and by its having strayed too far from the skirts of a wood, allowed myself, assisted by three other gentlemen, to surround it, and after an hour's hard chase to get it unhurt, though not before it was thoroughly fatigued, which might accelerate its death. During the time the animal remained in its usual vigour, its agility was incredible for so small a creature. It always took progressive leaps of from three to four, and sometimes of five yards, although seldom above twelve or fourteen inches from the surface of the grass; but I have frequently observed others in shrubby places, and in the woods, among plants, where they chiefly reside, leap considerably higher. When found in such places it is impossible to take them, from their wonderful agility, and their evading all pursuit, by bounding into the thickest part of the cover they can find." On the approach of cold weather it descends into the earth, and passes the winter in a state of torpidity. Another of these species has been described under the name of Labrador jumping mouse.[4] It is a very common animal in the fur countries as far north as Great Slave Lake, but Sir J. Richardson did not obtain any precise information regarding its habits.[5]

Genus Cricetus, Cuv. Teeth as in the genus *Mus*, but the tail is short, and clothed with hair, and the mouth is provided with cheek pouches, in which the species transport grain and other provisions into their subterranean chambers.

The most noted is the hamster (*Cricetus vulgaris*, Desm., *Mus cricetus*, Pallas; see Plate VIII., figure 10), an animal of variable colour, somewhat larger than a rat, of a thicker form, with a shorter tail. Although it occurs in Lower Alsace, it is rare in Europe to the west of the Rhine, but is widely spread from that river to the Danube on the south-west, and north-easterly through a vast extent of country into Siberia. It lives on roots, fruits, herbs, and other vegetable produce, and is said to be much attached to the grain of the liquorice plant. Some authors allege that it also preys occasionally on small birds, mice, &c. Though easily tamed, it is a fierce, resentful, pugnacious creature, and has been known to spring upon the muzzle of a horse, and hold on with its teeth till killed. When preparing for defence or attack, it empties its cheek pouches, and then so inflates them with air that its head and neck seem larger than the whole body. It then rises on its hind legs, and making a sudden spring, seizes on its adversary with the most obdurate tenacity. It will even spitefully grasp, and perseveringly maintain its hold of a piece of hot iron. Though the hamster occurs in great numbers, it is so far a solitary animal, that each inhabits a separate hole. It lays up during the summer season an ample and varied store, and is extremely injurious in many countries, from the quantity of grain which it conveys from time to time, in its cheek pouches, to its subterranean dwelling. These vary in depth and the number of their divarications with the age of the animal,—a young individual making them hardly a foot in depth, while the elders sink them four or five. The principal chamber is lined with hay, and serves as a sleeping room, while the other apartments contain the provisions.[6] These, it is said, will amount, for a single individual, to the weight of a hundred pounds. "On the approach of winter," says Dr Shaw, "the hamster retires into his subterraneous abode, the entry of which he shuts up with great care; and thus remaining in a state of tranquillity, feeds on his collected provision till the frost becomes severe; at which period he falls into a profound slumber, which soon grows into a confirmed torpidity, so that the animal continues rolled up, with all its limbs inflexible, its body perfectly cold, and without the least appearance of life. In this state it may be even opened, when the heart is seen contracting and dilating, but with a motion so slow as to be scarce perceptible, not exceeding fifteen pulsations in a minute, though in the waking state of the animal it beats a hundred and fifty pulsations in the same time. It is added, that the fat of the creature has the appearance of being coagulated, that its intestines do not exhibit the smallest symptoms of irritability on the application of the strongest stimulants, and the electric shock may be passed through it without effect. This lethargy of the hamster has been generally ascribed to the effect of cold alone; but late observations have proved, that unless at a certain depth below the surface, so as to be beyond the access of the external air, the animal does not fall into its state of torpidity, and that the severest cold on the surface does not affect it. On the contrary, when dug up out of its burrow, and exposed to the air, it infallibly awakes in a few hours. The waking of the hamster is a gradual operation: he first loses the rigidity of his limbs, then makes profound inspirations, at long intervals; after this he begins to move his limbs, opens his mouth, and utters a sort of unpleasant rattling sound. After continuing these operations for some time, he at length opens his eyes, and endeavours to rise, but reels about for some time, as if in a state of intoxication, till at length, after resting a small space, he perfectly recovers his usual powers. This transition from torpidity to activity requires more or less time, according to the temperature of the air, and other circumstances. When exposed to a cold air, he is sometimes two hours in waking; but in a warmer air the change is effected in half the time."[1]

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[1] *Fauna Boreali-Americana*, part i. p. 142.

[2] *Linn. Trans.* vol. viii. pl. vii.

[3] Ibid. vol. iv. pl. viii.

[4] Godman's *American Nat. History*, vol. ii. p. 97.

[5] *Fauna Boreali-Americana*, part i. p. 144.

[6] In the history of the hamster, as in that of other foreign species, the habits of which we have no means of ascertaining from personal observation, we are necessarily dependent for our information on the published works of authors of repute. We are sometimes, however, rather at a loss by which statement to be led, where there is a contrariety of evidence; as, for example, in regard to the species in question. "Il est *commun*," says Cuvier, "dans toutes les *contrées sablonneuses* qui s'etendent depuis le nord d'Allemagne, jusqu'en Siberie" (*Règne Animal*, t. i. p. 205); "Il *evite*," observes M. Desmoulins, "les *terrains sablonneux*, et ceux qui sont trop arrosés" (*Diction. Classique d'Hist. Nat.* t. viii. p. 34.). So in like manner regarding the entrances to their subterranean stores, there is a disparity of opinion. "Les cavités," according to M. Desmarest, "où elles (diverses semences, &c.) sont situées à deux pieds et demi ou trois pieds sous terre, et elles communiquent au dehors par deux galeries, dont *une, oblique, est le chemin d'usage ordinaire*, et l'autre, perpendiculaire, ne sert que dans les cas d'alerte" (*Mammalogie*, p. 310); while Dr Shaw observes, that "each hole has two apertures, the one descending obliquely, and *the other in a perpendicular direction*, and it is through this latter that the animal *goes in and out*" (*General Zoology*, vol. ii. p. 97.). We adduce these discrepancies to shew the difficulties which sometimes beset even the humble labours of a conscientious compiler. How almost insuperable they become in the way of original observation, may be inferred from the few precise additions to actual knowledge which we find amid the multiplied channels of modern information.

Numerous other species of this genus are described by naturalists, and the beautiful little South American animal called *chinchilla* (*C. laniger*, Geoff. and Desm.), so remarkable for the softness of its fur, has been usually classed with the hamsters.[2] New genera have been formed by M. Rafinesque Smaltz, and some other writers, for the reception of several of the reputed hamsters of North America, such as the sand rat, camas rat, pouched rat of Canada, &c.; but into the history of these we cannot enter.[3]

Genus Fiber, Cuv., Desm. Incisives $\frac{2}{2}$, molars $\frac{3-3}{3-3}$; $= 16$. Hind feet with a marginal row of long hairs, but not webbed.[4] Tail long, laterally compressed, scaly or granular, and thinly haired.

Of this genus the only species as yet distinctly characterized is *Fiber zibethecus*, or musk rat of Canada, commonly called the *musquash*. It is an animal of amphibious habits, measuring above a foot in length, with a thick flattish body, a short head, indistinct neck, thighs hid in the body, very short legs, and large hind feet. The fur greatly resembles that of the beaver, but is shorter, with the down coarser and of less value. Although it resists the water when alive, it is easily wetted after death. The musquash is peculiar to North America, where it extends from about north latitude 30°, almost to the mouth of the Mackenzie River in latitude 69°. They feed, for the most part, on vegetable substances (in summer they are said to devour the fresh water mussels), and their favourite abodes are small grassy lakes or swamps, or the grassy borders of slow-flowing streams which possess a muddy bottom. They are very prolific, bringing forth sometimes three broods in a season, but their numbers are often checked by a great mortality which attacks them at uncertain intervals, from some unknown cause. The districts in which they abound are also subject to frequent inundations, which, covering all the lower grounds, occasion the death of many by drowning, and in severe winters they are almost extirpated from certain districts by their swampy dwellings being frozen over. In such cases, Sir J. Richardson informs us, they are driven by famine to devour each other. In a state of nature they are rather watchful than shy, that is, they will approach close to a canoe, but will dive the instant they perceive the flash of a gun. According to Hearne they are easily tamed. Their fur is extensively used in the fabrication of hats,—between four and five hundred thousand skins being annually imported to Great Britain. The Indian hunters spear these animals through the walls of their mud houses.

Genus Arvicola, Cuv. Incisives $\frac{2}{2}$, molars $\frac{3-3}{3-3}$; $= 16$. Hind feet neither palmated nor ciliated. Tail round, haired.

This genus contains, among many other species, two small British quadrupeds,—the water rat (*A. aquatica*) and the short-tailed field mouse (*A. agrestis*). The former inhabits holes by the banks of lakes and rivers. In this country, its disposition, so far as yet observed, is herbivorous, but French and Italian naturalists state that it preys also on insects, reptiles, and the spawn of fishes. The latter is very common in fields, gardens, and the outskirts of woods, in all of which it sometimes occasions no small damage. Although M. Desmarest assigns "l'ancien continent" as the geographical range of the genus Arvicola, yet several species inhabit North America. Indeed the French author has himself described *A. xanthognathus* as native to the shores of Hudson's Bay. Of the species of Northern Asia, one of the most singular is the economic rat (*A. economus*, Desm.), so called from the great skill and sagacity which it displays in providing the supplies of winter. This labour rests chiefly with the female,—the male during summer leading a solitary life, dwelling in old deserted holes, and feeding on berries and other produce of the season. When cold weather approaches, both sexes wisely betake themselves to the same hole. The occasional migrations of this species are scarcely less remarkable than those of the lemming. The cause of these movements is quite unknown, although Pallas imagines (and every one is entitled to indulge that poetical and pleasing attribute) that they are occasioned, at least in Kamtschatka, by some uneasy sensation produced by the subterranean fire of that volcanic region. M. Bosc conceived that he had found this species in the forest of Montmorency, and we have also been informed of its supposed occurrence in Switzerland. Although those localities are somewhat doubtful, we must at the same time bear in mind, that several of the species are very extensively distributed,—*Arvicola pennsylvanicus* of Ord (commonly called Wilson's meadow-mouse) being by some regarded as identical with our *A. agrestis*.

Genus Georychus, Illig. *Lemmus*, Desm. Scarcely differs from the preceding, except in the shortness of the ears and tail, and the larger and stronger claws, more fit for digging.

We here place the celebrated lemming (*Mus lemmus*, Linn., *Lem. Norvegicus*, Desm.), of the migratory movements of which we have such singular records. It is a northern animal, an inhabitant of the mountains of Norway and Lapland, of the size of a rat, and clothed with fur varied by black and tawny. The specimens from different localities do not altogether accord either in size or colour. The lemming differs from many of its congeners, and indeed from several species of its own genus, in having five well developed toes to the anterior feet, instead of four toes and a rudimentary thumb. We have heard less of late of this animal than might have been anticipated from the extraordinary accounts which the preceding century furnished of its history. The lemmings were described as natives of the mountains of Kolen, in Lapland, and were said to appear once or twice in a quarter of a century " in numbers numberless," advancing in a straight line, unchecked by hill or dale, by lake or river, and devouring in their onward journey " every green thing." Even the anxieties of maternity do not slacken their march, for they have been known to produce their offspring while journeying, and to proceed as if nothing had happened, with a young one between their teeth, and another on their back.[1] Innumerable bands were seen to march from the Kolen, through Nordland and Finmark, to the Western Ocean, which, nothing daunted, they immediately entered, and after swimming about for some time, as might be expected, perished. Other bands were observed to take their route through Swedish Lapland to the Bothnian Gulf, where they were drowned in the same manner. When opposed by the peasants, they stood still and barked at them; and they themselves were not only barked at in return, but were swallowed in great quantities by the lean and hungry dogs of Lapland. The advent of these vermin is regarded as the omen of a bad harvest. They are followed in their journeys by bears, wolves, and foxes, which prey upon them incessantly, and regard them as the most delicious food.[2] These excursions seem to augur a rigorous winter, of which the lemmings in some way appear forewarned. For example, the season of 1742, remarkable for its severity throughout the circle of Umea, was comparatively mild in that of Lula, although situate further to the north; the lemmings migrated from the former, but remained stationary in the latter district. Whatever may be the motive of these journeys, they are certainly executed with surprising perseverance, and with the universal accord of the whole nation,—the *officina murium* pouring forth its entire hordes, and leaving scarce a remnant in their ancient habitation. The greater proportion perish before they reach the sea, and of course few survive to return to their ancestral homes. They do, however, endeavour to return; for the object of their travel to a far country, whatever it may be, is not to found a multiplied or more extended empire. This indeed is evident from the comparatively local restriction of the species; for the true lemming of the Scandinavian Alps does not appear to occur even in Russian Lapland; and the kind which inhabits the countries in the vicinity of the White and Polar Seas, as far as the mouths of the Obi, is a species or strongly marked variety, smaller by at least one-third, and of a different aspect and colour.[3] Their migratory propensities are, however, entirely the same in different countries; for the species which dwells among the northern extremities of the Ural Mountains, emigrates sometimes towards Petzora, at other times towards the banks of the Obi, and is followed, as usual, by troops of carnivorous and insatiate foes.[4] The domestic manners of the species are said to present this discrepancy, that the Norwegian lemmings lay up no provisions, and have only a single chamber in their subterranean dwelling-places, whereas the lesser kind excavate numerous apartments, and are provident of the winter season, by storing up ample magazines of that species of rein-deer moss called Lichen rangiferinus.[5]

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[1] *General Zoology*, vol. ii. p. 97.

[2] The chinchilla is now regarded as generically distinct. We shall notice it at the conclusion of our present order.

[3] See *Fauna Boreali-Americana*, part i., and Lesson's *Manuel de Mammalogie*.

[4] "Pieds de derrière demi palmés." Cuvier. "There is no vestige of a web." Richardson.

Many other lemmings occur in Siberia and the Tartarian deserts, and several in North America. Of the latter we may mention that from Hudson's Bay, *G. Hudsonius*, one of the most northern of known quadrupeds. It does not appear to have been met with as yet in the interior of America, but inhabits Labrador, Hudson's Straits, the coast from Church-hill to the extremity of Melville Peninsula, and the desolate islands of the Polar Sea. Its manners are imperfectly known, but Hearne states that it is so easily tamed, that if taken even when full grown, it will in a day or two become reconciled to captivity, and will voluntarily creep into its master's bosom. This species has no external ears, and scarcely any tail. " Les deux doigts du milieu," says Cuvier, " aux pieds de devant du male, ont l'air d'avoir les ongles doubles parceque la peau du bout du doigt est calleuse, et fait une saillie sous la pointe de l'ongle,—conformation qui ne s'est encore rencontrée que dans cet animal."[6] Sir J. Richardson, however, informs us, that the lower layer of the claw appeared to him to be not an enlargement of the callus, but rather of the same substance as the superior portion or nail proper.

GENUS DIPUS, Gmel. Incisors $\frac{2}{2}$, molars $\frac{3-3}{3-3}$, or $\frac{3-3}{4-4}$; $= 16$ or 18. Head broad. Eyes large. Ears long and pointed. Anterior feet with four toes, and a nailed wart in place of thumb. The posterior extremities of great length, and terminated by three or five toes. Tail very long, cylindrical, covered throughout with short hair, and terminated by a tuft.

The jerboas, called two-footed rats by ancient writers, are nocturnal animals, of subterranean habits, native to the central countries of the Old World. They feed on fruits and roots. One of their most remarkable characters consists in this, that the three middle toes are all supported by a single metatarsal bone, which thus resembles the canon bone of the ruminating tribes, an osteological feature unique, we believe, in the rodential order. Such of the species as have only three toes, have but a single metatarsal bone to the whole. The *Dipus jerboa (Mus sagitta*, Pall.) is abundant in Barbary, in Upper and Lower Egypt, and Syria, and makes its appearance again in more northern countries between the Tanais and the Volga. It feeds chiefly on bulbous plants, and is remarkable for the extreme celerity of its course, which it effects by a series of long and rapid bounds. Though its tail, from the cruel experiments of M. Lepechin, appears to be of great use in locomotion, it is not by any means thick and muscular like that of the kangaroo. The jerboa usually walks on all fours, but when alarmed it seeks its safety by prodigious leaps, executed with great force and rapidity. When about to spring, it raises its body by means of the hinder extremities, and supports itself at the same time upon its tail, while the fore feet are so closely pressed to the breast, as to be scarcely visible. Hence, probably, its ancient name of dipus, or two-footed. It then leaps into the air, and alights upon its four feet, but instantaneously erecting itself, it makes another spring, and so on in such rapid succession, as to appear as if rather flying than running. The experiments above alluded to consisted in maiming or cutting off the tails of these poor creatures. In proportion as that organ was reduced in length, their power of leaping diminished; and, when it was entirely lopped away, they not only could not run at all, but fell backwards whenever they attempted to raise themselves with a view to their accustomed spring. "The jerboa," says Bruce, "is a small harmless animal of the desert, nearly the size of a common rat, the skin very smooth, and the ends of the hairs tipt with black. It lives in the smoothest plains or places of the desert, especially where the soil is fixed gravel, for in that chiefly it burrows, dividing its hole below into many mansions. It seems to be apprehensive of the falling in of the ground; it therefore generally digs its hole under the root of some spurge, thyme, or absynthium, upon whose root it seems to depend for its roof not falling in and burying it in the ruins of its subterranean habitation. It seems to delight most in those places that are haunted by the cerastis, or horned viper. Nature has certainly imposed this dangerous neighbourhood upon the one for the good and advantage of the other, and that of mankind in general. Of the many trials I made, I never found a jerboa in the body of a viper, excepting one in that of a female big with young, and the jerboa itself was then nearly consumed."[1] This species is used as food, and its flesh, in taste, is scarcely distinguishable from that of a young rabbit. It is described at a remote period by ancient authors, and is represented in some of the earliest medals of the Cyrenaicum, sitting beneath an umbellated plant (supposed the *Silphium*), the figure of which is likewise preserved on the silver medals of Cyrene. The *Dipus jaculus* inhabits the Tartarian deserts, and other species occur in different regions, from the shores of the Caspian Sea to the banks of the rivers of Siberia. We here figure an African species, the *Dipus hirtipes* of Lichtenstein. (See Pl. VIII., figure 11.)

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[1] *Mammalogie*, p. 288.

[2] See *Quarterly Review*, vol. xlvii. p. 338, and Dodsley's *Annual Register*, for 1769.

[3] Schreber, pl. 195, B.

[4] Pallas, *Novæ Species Quadrupedum e glirium ordine.*

[5] *Dict. Class. d'Hist. Nat.*, article *Campagnol.*

[6] *Règne Animal*, t. i. p. 208.

The largest species of the genus, as formerly constructed, is the Cape jerboa, *Dipus caffer*, Gmel. It differs from the others in having four molar teeth on each side of both jaws, five toes to the anterior feet, and only four to the posterior, the latter armed with broad claws almost resembling hoofs. It measures about a foot in length, exclusive of the tail, which extends fifteen inches. This species is remarkable for its great strength and activity, which enable it to spring from twenty to thirty feet at a single bound. It dwells in deep burrows in the mountainous regions to the north of the Cape of Good Hope, and is known to the Dutch colonists under the name of *springen haas*, or jumping hare. In consequence of the peculiarities of structure just referred to, it has been formed by Illiger into a separate genus, under the name of PEDETES (*Helamys*, F. Cuvier). (See Plate IX., figure 1.)

GENUS SPALANX, Guldenstaedt. *Aspalax*, Olivier, Desm. Teeth as in the rats and hamsters, but the incisives more projecting and exposed. Legs very short; all the feet furnished with five toes, with flat thin nails. External ears and tail scarcely perceptible.

The singular animal (*Mus typhlus* of Pallas) which forms the type of this genus, resembles the mole in its habits,—throwing up the earth from its burrows in the same manner, though furnished with much less powerful limbs. It measures nearly ten inches long, has a thick cylindrical body, a large triangular head, and no apparent eyes. Beneath the skin, however, there are small black points resembling eyes, although their functions, as organs of vision, are difficult to understand, in as far as they are covered over by skin and hair. "Whether the spalax be absolutely blind, or whether it receives any perception of light through the medium of the eye as an organ, does not sufficiently appear by what has hitherto been said by its describers. The presence of what may be called the vestige of an organ, seems perfectly consistent with other instances in which the application of such imperfect organ is not at all to be traced. On the contrary, it accords with that apparent unwillingness in nature to depart from prescribed laws. The total absence of an accustomed organ is much more anomalous in nature than the complete inutility of an imperfect one."[2] It has been generally assumed that the Greeks described our common mole *as blind*, under the name of ασπαλαξ. and modern authors, knowing that the sleek inhabitant of our pastures is possessed of eyes, though small ones, have prided themselves on their supposed correction of an ancient error; but the observations of Olivier go to prove that the mole of the Greeks was not the species of western Europe, but the animal in question, which spreads through Asia Minor into Persia and the south of Russia, between the Tanais and the Wolga. The original error probably lay with the Latin writers, who translated the word ασπαλαξ into talpa, and then applied the term to the mole of Europe. We may add, however, that Professor Savi of Pisa is of opinion that the aspalax is to be regarded as identical with the species of mole (*Talpa cæca*) which he discovered in the Apennines,[3] and which Baron Cuvier says is "tout à fait aveugle,"[4] by which we presume he merely means that its eyes are covered by the skin. M. Charles Lucien Bonaparte likewise regards these species as synonymous.[5]

We may here briefly notice the genus BATHIERGUS of Illiger, which, with several attributes of the preceding genus, is distinguished by four molars on each side both above and below, by a small though perceptible eye, and a short tail. The sand mole (*B. maritimus*, Plate IX., figure 2), as the larger species is usually called, is an animal of the size of a rabbit, which occurs abundantly along the sandy shores of the Cape of Good Hope, where it sometimes excavates the ground in such a manner as to produce inconvenience, if not danger, to horsemen. Another species, called the Cape rat (*B. capensis*), is destructive in gardens and pleasure grounds. A third has been described under the title of *B. hottentotus*, by MM. Lesson and Garnot.[6]

For the genera GEOMYS and DIPLOSTOMA of M. Rafinesque, and a few other groups of the Rodential Order, the characters of which we cannot here detail, we must refer the reader to the works quoted below.[7]

GENUS CASTOR, Linn. Incisives $\frac{2}{2}$, molars $\frac{4-4}{4-4}$; $= 20$. Eyes small. Ears short and rounded. Five toes to each foot, those of the hinder extremities united by a web or membrane. Tail broad, depressed, ovular, naked, and scaly. Two pouches (in the male) on each side of the genitals, containing an unctuous matter called castoreum.

As the description of the beaver, which alone constitutes our present genus, is recorded in almost every book of natural history, we shall here confine ourselves to a few particulars regarding its general habits, and as its history, as given by the traveller Hearne, has been characterized by competent authority as the most accurate which has been yet presented to the public, we shall here abridge it for the benefit of the same. We may, however, premise by observing, that naturalists have not yet been able to establish any distinctive characters between the gregarious beavers of North America, and the few that still survive in isolated pairs along the banks of a few great European rivers, such as the Rhone, the Rhine, and the Danube.[1] Those of Europe seem of somewhat larger dimensions, and of a paler coloured fur. (See Plate IX., figure 3.)

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[1] *Travels*, vol. v. p. 121.

[2] Griffith's Edition of the *Animal Kingdom*, vol. iii. p. 162.

[3] *Memorie Scientifiche*, Decade prima.

[4] *Règne Animal*, t. i. p. 131. Since the above was written, we have happened to cast our eyes on a supplementary note by Baron Cuvier, in which he states as follows: "La taupe appelée *aveugle* par M. Savi, ne l'est pas entièrement; ses paupières ont aussi une ouverture, mais encore plus petite que dans la taupe commune. On a nié l'existence du nerf optique de la taupe commune;—je me crois en etat de le démontrer et dans tout son trajet." *Ibid.* p. 580.

[5] *Iconographia della Fauna Italica.*

[6] *Voyage de la Coquille*, Pl. 2.

[7] Desmarest's *Mammalogie*, and Richardson's *Fauna Boreali-Americana.*

The situation of the beaver houses in America is found to be various. Where the animals are numerous, they inhabit lakes, ponds, and rivers, as well as those narrow creeks which connect the lakes together. They generally, however, prefer flowing waters, probably on account of the advantages afforded by the *current* for transporting the materials of their dwellings. They also prefer deepish water, no doubt because it yields a better protection from the frost. But it is when they build in small creeks or rivers, the waters of which are liable to dry or be drained off, that they manifest that beautiful instinct with which Providence has gifted them,—the formation of dams. These differ in shape according to the nature of particular localities. Where the water has little motion the dam is almost straight; where the current is considerable it is curved, with its convexity towards the stream. The materials made use of are drift wood, green willows, birch, and poplars; also mud and stones intermixed in such a manner as must evidently contribute to the strength of the dam; but there is no particular method observed, except that the work is carried on with a regular sweep, and that all the parts are made of equal strength. "In places," says Hearne, "which have been long frequented by beavers undisturbed, their dams, by frequent repairing, become a solid bank, capable of resisting a great force both of ice and water; and as the willow, poplar, and birch generally take root and shoot up, they by degrees form a kind of regular planted hedge, which I have seen in some places so tall, that birds have built their nests among the branches."[2] Their houses are formed of the same materials as the dams, with little order or regularity of structure, and seldom contain more than four old, and six or eight young beavers. It not unfrequently happens that some of the larger houses have one or more partitions, but these are only posts of the main building left by the sagacity of the beaver to support the roof, for the apartments, as some are pleased to call them, have usually no communication with each other except by water. Those travellers who assert that the beavers have two doors to their dwellings, one on the land side, and the other next the water, manifest, according to Hearne, even a greater ignorance of their habits than do those who assign to them an elegant suite of apartments, for such a construction would render their houses of little use either as a protection from their enemies, or as a covering from the winter's cold. Neither is it true that these animals drive stakes into the ground when building; they lay the pieces crosswise and horizontal. It is equally inaccurate to state that the wood work is first finished, and then plastered, for both houses and dams consist from the foundation of a mingled mass of mud and wood, mixed with stones, when such can be obtained. They carry the mud and stones with their fore-paws, and the timber between their teeth. They always work in the night, and with great expedition. They cover their houses late every autumn with fresh mud, which freezing when the frost sets in, becomes almost as hard as stone; and thus neither wolves nor wolverines can disturb their well-earned repose. When walking over their work, and especially when about to plunge into the water, they sometimes give a peculiar flap with their broad heavy tails; but they do not use these parts exactly as a mason uses his trowel, for a tame beaver will flap by the fireside, where there is nothing but dust and ashes.

The favourite food of beavers is the plant called *Nuphar luteum*, which bears a resemblance to a cabbage stalk, and grows at the bottom of lakes and rivers. They also gnaw the bark of birch, poplar, and willow trees. But during the bright summer days which clothe even the far northern regions with a luxuriant vegetation (the more beautiful as contrasted with the rigorous and long enduring winter) a more varied herbage, with the addition of berries, is consumed. When the ice breaks up in spring they always leave their embankments, and rove about until a little before the fall of the leaf, when they return again to their old habitations, and lay in their winter stock of wood. They seldom begin to repair the houses till the frost sets in, and never finish the outer coating till the cold becomes pretty severe. When they erect a new habitation, *they fell the wood early in summer*, but seldom begin building till towards the latter end of August. Some tame beavers kept by Hearne became extremely attached to human society, and were also remarkably fond of rice and plum-pudding. They would even eat freely of partridges and fresh venison. Kalm mentions a tame beaver which belonged to a gentleman of New York, and was in the habit of going about the house like a dog. A cat which inhabited the same dwelling, on producing kittens took possession of the beaver's bed without any opposition being offered; and ere long, when the cat went out, the beaver used to take a kitten between his paws, and hold it to his breast, as if to keep it warm, till the return of the proper parent.[3]

Dr Richardson informs us that the flesh of these animals is much prized by the Indians and Canadian voyagers, especially when roasted in the skin, after the hair has been singed off. This of course makes it an expensive luxury, the enjoyment of which it requires all the influence of the fur traders to restrain. Beavers are said to pair in February, to carry their young about ten weeks, and to bring forth from four to eight cubs by the middle or end of May. In regard to the geographical distribution of these highly interesting creatures, Pennant fixes their southern range in Louisiana, about latitude 30°, not far from the Gulf of Mexico, while Mr Say assigns as their limit the confluence of the Ohio and Mississippi, about seven degrees farther north. In the higher latitudes, their extension seems restricted by the absence or deficiency of wood, the districts called the Barren Grounds not yielding enough even of willows for their subsistence. Many are known to occur as high as latitude 68°, on the banks of the Mackenzie, the largest and best wooded of the American rivers that discharge themselves into the icy basin of the Polar Sea. The Iroquois are the greatest beaver catchers in Canada. There is no doubt that great injury has resulted from the indiscriminate capture of old and young, and the too frequent *trenching* of the same dams,—evils which the Hudson's Bay Company are at last endeavouring to remedy by the adoption of more prudent measures. "In the year 1743, the imports of beaver skins into the ports of London and Rochelle, amounted to upwards of 150,000; and there is reason to suppose that a considerable additional quantity was at that period introduced illicitly into Great Britain. In 1827, the importation of beaver skins into London, from more than four times the extent of fur country than that which was occupied in 1743, did not much exceed 50,000."[4]

There is an amphibious animal called the Coipu (*Mus coipus*, Molina), which dwells by the rivers of South America, and is allied to the beaver in many of its characters, except that its tail is narrow and elongated. Its fur, much used in the manufacture of hats, is known to merchants under the name of *racoonda*, and is imported in great quantities to Europe. This animal inhabits Chili, is very abundant in the provinces of Buenos Ayres and Tucuman, but rare in Paraguay. It is described by Desmarest as a hydromys (*H. coypus*[1]), and is mentioned by Azara under the name of *Quouiya*.[2] It is now regarded as forming a distinct genus under the title of MYOPOTAMUS, as first proposed, we believe, by M. Commerson.

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[1] Nous n'avons pu encore constater, malgré des comparaisons scrupuleuses, si les castors ou bièvres qui vivent dans des terriers le long du Rhône, du Danube. du Weser et d'autres rivières, sont différents par l'espèce de celui d'Amerique; ou si le voisinage des hommes est ce qui les empêche de bâtir."—*Règne Animal*, t. i. p. 214. "Nous avons cru devoir réunir, d'après MM. Cuvier, le castor d'Europe à celui du Canada, surtout d'après l'observation récente de ses mœurs en captivité, qui prouve évidemment que ce castor a, comme l'autre, un penchant inné à construire." *Mammalogie*, p. 278.

[2] *Journey to the Northern Ocean.*

[3] *Travels in North America.*

[4] *Fauna Boreali-Americana*, part 1st, p. 108.

DIVISION II. Clavicles incomplete or nonexistent.

GENUS HYSTRIX, Linn. Incisives $\frac{2}{2}$, molars $\frac{4-4}{4-4}$; = 20. Muzzle broad and blunt. Ears short and rounded. Tongue beset with prickly scales. Anterior feet with four toes and a rudimentary thumb, the posterior with five, the whole armed (except the small anterior thumb) with strong claws. Body protected by strong sharp-pointed spines of different length, intermingled with the hairs.

This genus is composed of four or five animals of very extraordinary aspect, known under the name of porcupines. They occur in Europe, Asia, Africa, and America, and have recently been formed into several minor generic groups, of which we shall give a brief sketch. All the species feed on fruits, roots, and grain, and either dig themselves subterranean dwellings, or seek retirement in the secure hollows of ancient trees.

The restricted genus HYSTRIX, Cuv., characterized by the dilatation of the muzzle and nasal bones, contains the European porcupine (*H. cristata*, Linn.), an animal which occurs in the south of Italy, Spain, Sicily, and Barbary. (See Plate IX., figure 4.) Indeed, the identical species, or one closely allied, extends to the Cape of Good Hope, and spreads from Persia into Hindustan. It measures above two feet in length. Its quills are very long, ringed with brownish-black and white. There is a kind of crest or mane of long bristles on the head and nape. The tail is short, and furnished with truncated hollow quills, suspended by a narrow pedicle, so that they rattle when the creature walks, like a half-filled quiver. Mr Brydone mentions that the porcupine is frequent in Sicily, in the district of Baiæ, and that he killed several during a shooting excursion in the Monte Barbaro. He dined upon his game, but found it luscious, and soon palling upon the appetite.[3] The singular aspect of this animal seems to have attracted the attention of the lovers of natural history at a very early period, and many fabulous attributes were added to the character of a creature in itself sufficiently curious. It was said to possess the power of darting its quills at pleasure with great force, and to a considerable distance, against its enemies; and Claudian observes, that it is itself at once the quiver, the arrow, and the bow:

> "Ecce, brevis propriis munitur bestia telis,
> Externam nec quærit opem, fert omnia secum
> Se pharetrâ, sese jaculo, sese utitur arcu!"

We may add, that Agricola states the Italian porcupine to be not indigenous to the south of Europe, but imported from India or Africa.

In the genus ATHERURA, Cuv., the head and muzzle are not dilated, and the tail is long, though not prehensile. It contains the *Hystrix fasciculata*, Linn., *Mus fasciculatus*, Desm., a native of India and the peninsula of Malacca.

The genus ERETISON, F. Cuvier, of which the cranium is flat, and the muzzle not dilated, the tail of medium length, and the quills short and half concealed by long hair, contains the well-known Canada porcupine (*H. dorsata*, Linn.). This species is distributed over a considerable extent of North America, from the 37° to the 67°. According to Dr Harlan, it makes its dwelling-place beneath the roots of hollow trees. It dislikes water, is cleanly in its habits, sleeps much, and feeds chiefly on the bark and leaves of *Pinus canadensis* and *Tilia glabra*. It is also fond of sweet apples and Indian corn. In the fur countries it is most numerous in sandy districts, covered with *Pinus Banksiana*, on the bark of which it delights to feed. Its spines are detachable by the slightest touch (some say by an act of volition on the part of the animal), and not unfrequently occasion the death both of dogs and wolves. Its flesh tastes like flabby pork, and, though relished by the Indians, is nauseous to the palate of a European.

The genus SYNETHERES of F. Cuvier (*Couendu*, Lacepede), contains certain South American species with prehensile tails, such as *H. prehensilis*, Linn., and *H. insidiosa*, Lichtenstein. (See Plate IX., figure 5.) The feet have only four claws, armed with nails, and they differ from the preceding species in their habit of climbing trees. Other generic groups have been proposed in relation to the genus Hystrix, but without having met with general reception on the part of naturalists.[4]

GENUS LEPUS, Linn. Incisives $\frac{4}{2}$, molars $\frac{6-6}{5-5}$; = 28. Anterior feet with five toes, posterior with four. Tail short. Cœcum very large, pouched, and divided by a spiral valve.

The species of this genus, familiarly known under the name of hares and rabbits, are spread over almost all the regions of the earth, from the tropical regions of Africa and America, to the islands of the Polar Sea. Their most distinctive character consists in their upper incisives being double, that is, each has a smaller one behind it. The soles of the feet, and the inside of the mouth (a character remarked by Aristotle), are covered with hair. The genus is not only one of considerable extent, but extremely natural,—the species of which it is composed corresponding both to the principal characters, and also to several others which are secondary and unessential, such as the colour of the fur, which is usually of a reddish-grey, with the eye placed in a spot of paler hue. The abdomen and under side of the tail seem almost always white, and the tips of the ears black. They are all of a timid disposition, extremely swift in their movements, and valuable to the human race, not more on account of the value of their furs, than of their nutritive and pleasant flavoured flesh. Several of the species resemble each other so closely as to be with difficulty distinguished.

The common hare (*Lepus timidus*) is known all over Europe, and a great part of Russia, Asia Minor, Syria, &c. The varying hare (*Lepus variabilis*) is somewhat larger in the body, with rather shorter ears and tail, its fur in summer being of a bluish-grey, and changing to white in winter. This remarkable alteration is said to take place in the following manner:—About the middle of September the grey feet become whitish, and before the end of the month all the four feet are white, and the ears and muzzle of a brighter aspect. The white colour gradually ascends the legs and thighs, and beneath the grey hair whitish spots may be observed, which continue to increase till the end of October; but still the back continues grey, while the eye-brows and ears are nearly white. From this period the change is rapid, and by the middle of November the whole fur is white, excepting the tips of the ears, of which the black is permanent. The back becomes white within eight days, and during the whole of this singular mutation no hair is shed. Hence it appears that the fur itself, though altered in aspect, remains unchanged. It continues white till the month of March, or later, according to the season, after which it again becomes grey. But the spring change differs in this respect from that of the early winter, that the hair is then completely shed.[1] This animal inhabits the alpine parts of Europe, but does not extend to the extreme north, as supposed by Pennant, the species of that locality being now distinguished by the name of Polar hare, *Lepus glacialis*, Leach. The size of the latter is equal to that of the largest English hare. It does not burrow, but seeks shelter among large stones and the crevices of rocks. Its flesh is more juicy than that of our own alpine or varying hare. The polar species is common in North America, but does not seem to advance southwards beyond the 58th parallel, and does not occur in wooded countries, though often seen in the vicinity of thin clumps of spruce fir. It extends to Melville Island. Several other species occur in America. The American hare, commonly so called (*Lepus Americanus*), bears a great resemblance to a rabbit, and seldom weighs more than four pounds. It is common in all the woody districts, and 25,000 have been taken at a single trading post in one season. They are imported into Britain under the name of rabbit-skins. The prairie hare (*Lepus Virginianus*) is a much larger animal, weighing from seven to eleven pounds. It can leap above twenty feet at a single bound. We cannot here allude to the species of southern latitudes.[2]

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[1] *Mammalogie*, p. 296.

[2] *Essai sur l'Hist. Nat. de Paraguay*, t. ii. p. 5. See also *Annal. du Mus.* t. vi. pl. 35.

[3] *Tour in Sicily.*

[4] See *Memoires du Museum*, t. ix. p. 413.

The rabbit (*Lepus cuniculus*), now so common throughout the temperate and southern parts of Europe, is supposed to have been of African origin, and first imported into Spain. It differs greatly from the hare in its gregarious habits, its subterranean life, the whiter colour of its flesh, and less perfect state of the young when first produced. It is also much more prolific.[3]

A few species of the old genus Lepus, of which the ears are shorter, the limbs of more equal length, the clavicles almost perfect, and the tail wanting, form the generic group now called LAGOMYS. We shall here mention as an example the *Pika* of Northern Asia (*Lag. alpinus*, Plate IX., figure 6). It is about the size of a guinea pig, and inhabits the tops of high mountains, such as those of the Altaic range, and the cold heights of Siberia. It dwells in burrows, the clefts of rocks, and even (when it can get them) in the trunks of trees, and is sometimes gregarious, sometimes solitary. Towards the middle of August it collects and prepares a great mass of hay and other herbage for winter use, and in this labour several join together. These heaps sometimes measure more than eight feet in diameter, and equal or exceed the height of a tall man. This admirable instinct has rendered these little animals celebrated throughout the countries they inhabit. Their precious stores, however, are often discovered by the Siberian hunters of the sable, who convert them from their intended uses into fodder for their hungry horses.

In immediate succession to the porcupines, hares, and pikas, Baron Cuvier places those groups of the Rodential Order, which Linnæus and Pallas combined under the generic name of CAVIA, and of which the well known guinea-pig affords a familiar example. They are all natives of the New World, and, except in the imperfect condition of their clavicles, offer such disparity of structure as have induced, in comparatively recent times, the formation of the following genera.

GENUS HYDROCHÆRUS, Erxleben. Incisives $\frac{2}{2}$, molars $\frac{4-4}{4-4}$; = 20. Muzzle deep and blunt. Ears rather small and rounded. Anterior feet furnished with four toes, the posterior with three, all webbed, and terminated by strong blunt claws. No tail. Mammæ twelve. Fur coarse and thin.

The only known species of this genus is the capybara or water hog of South America (*H. capybara*, Erx., *Sus hydrochœrus*, Linn.). It sometimes measures upwards of four feet in length, and is the largest of all the Rodentia. Its habits are aquatic and gregarious. It abounds in the rivers of the Oroonoko, the Apure, and the Cassiquiare, and is much preyed on by jaguars while on shore, and by crocodiles in the water. Its flesh is excellent, and was eaten by the missionary monks during Lent along with their turtle, on the score, we presume, of its amphibious habits. Precise views of the exact nature of all mammalia are sometimes inconvenient. These animals are so numerous in many of the marshes and moist savannahs of the Llanos as greatly to injure the adjoining pastures. They browse chiefly on that kind of grass which serves best for fattening horses, called *chiguirero* or chiquiré's grass, so designated from one of the native names of the capybara. Their flesh is made into hams, and would be less disagreeable if free from the strong odour of musk with which it is impregnated. These creatures are of gentle disposition, capable of considerable attachment in a state of domestication, and not greatly fearing the human race even in their natural and unreclaimed condition. When attacked they endeavour to escape by flight; and, when overtaken, they can scarcely be said to stand upon the defensive, but as they possess great natural strength both in their incisive teeth and grinders, they have been known, in their dying agonies, or when pushed to a desperate extremity, to inflict so severe a wound as to tear the flesh from the paw of a jaguar or the leg of a horse. They were observed by Humboldt in all the great rivers, either swimming about like dogs, with the head and neck above water, or diving from the surface to escape their pursuers. They possess the power of remaining submerged for seven or eight minutes.

GENUS CAVIA, Illiger. Teeth the same in number as in the preceding genus. Feet not palmated. Only two ventral mammæ.

This genus is also believed to contain only a single species, well known throughout Europe in a domestic state under the name of guinea-pig (*Cavia cobaja*, Pallas, *Mus porcellus*, Linn., see Plate IX., figure 7 *a*). Like most reclaimed animals, it varies in its markings, the usual colours being a mixture of white, black, and reddish-brown. It is of an amazingly prolific nature, being capable of bringing forth when not more than two months old, and that same period only elapsing between the production of each brood. The number of young at a birth varies with the age of the parent, from four to twelve. It has been calculated that a single pair may prove the parent stock of a thousand in a year. The wild or native guinea-pig is supposed to be an animal of corresponding size and structure, but of a uniform reddish-grey or brown colour, paler on the under surface. It is called *aperea*, and is indigenous to the countries between the Plata and the Amazon. (See Plate IX., figure 7 *b*.) It abounds in Paraguay, and also occurs at Buenos Ayres, inhabiting brushwood by the banks of rivers, and feeding chiefly during the evening and morning twilight. A singular disparity exists in the productive powers of these animals in the natural and domestic state, the aperea being said to bring forth only one or two at a birth, and to breed not more than once a year. Some regard this as a strong fact against their probable identity; but when we consider that the teats are only two in number in each variety, we ought rather to consider the extreme fertility of the domestic kind as in a great measure the result of high and careful keeping. "Nous avons comparé," says Ant. Desmoulins, "des crânes du cobaie domestique à ceux du cobaie sauvage, et nous n'y avons pas trouvé de différence entre eux. Par-là se trouve péremptoirement réfuté tout ce qu'a dit Gall sur la cause organique de cette activité gènitale dont les extrêmes ne sont nulle part plus tranchés qu'entre les deux états sauvage et domestique de cette espèce."[1] In speaking of the domestic breed M. Desmarest observes, "qu'il ne boive jamais." Perhaps this means that they do not like water, but we can vouch for their drinking a great deal of milk. The French author adds:—"C'est un animal d'un naturel doux et docile, mais il est sans aucune intelligence, et incapable de s'attacher à son maître."[2] Now, in contradiction to the last part of the indictment, we have seen this animal exhibit great discrimination in singling out and creeping kindly into the protecting arms of a favourite and well-known individual of a pet-loving community. It is rather remarkable that the guinea-pig is never used as food in European countries, when we know that the aperea is esteemed for that purpose, and is pursued as game in its native regions.

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[1] *Edin. Phil. Journal*, vol. ii. p. 15.

[2] See the article *Lievre* of *Dict Class. d'Hist. Nat.* t. ix. p. 378.

[3] It is curious that naturalists should differ in several important points in the history of a creature so common. "They are born covered with hair, and with their eyes open." Griffith's *Animal Kingdom*, vol. iii. p. 217. "The eyes and ears, at birth, are imperfect, the skin is destitute of hair, and the limbs unfit for locomotion." Fleming's *British Animals*, p. 21.

The animals called *agoutis* in some measure represent our hares and rabbits in the Antilles and South America. They form the genus Dasyprocta of Illiger. The common species (*Cavia agouti*, Linn.) is gregarious, living in troops of about twenty individuals. It inhabits woods, resembles a rabbit in its gait and aspect, but equals a hare in size. Its flesh is good, partaking of the qualities of these two animals combined. The agouti occurs in Guiana, Brazil, Paraguay, and some of the West Indian islands. It is said to be extremely voracious, devouring all kinds of vegetable substances, and is much attached to nuts. In a state of confinement, it will speedily gnaw its way through a door. The Patagonian cavy of Pennant and Shaw (*Das. Patachonica*), called by Azara the pampa hare, likewise belongs to this genus. It inhabits the pampas or great plains, and usually occurs in pairs. Azara was informed that this species produces its young in the burrows dug by the *viscache*. It extends far southwards into the colder countries of the New World, and was observed by Narborough and other voyagers to be very abundant in the vicinity of Port Desire, in the 47° south latitude, as well as at Port Saint Julian, some degrees farther south.

The pacas (genus *Cœlogenys*, F. Cuvier) resemble the agoutis in their teeth, but they have a small additional inner toe on the fore feet, and one (equally small) on either side of the hinder ones, making five toes to each extremity. There seem to be two species, the brown and the yellow paca (*Cel. subniger* and *fulvus*), both natives of Brazil and Guyana. They are excellent as articles of food, and Buffon and later writers have advised their importation into Europe for the uses of the table.

We shall here close our sketch of the Order Rodentia with a short notice of an animal, the exact position of which in the order has not yet been rigorously determined. We allude to the *chinchilla*, a South American species, greatly esteemed for the fineness and beauty of its fur, which forms a frequent adornment of the fair sex in Europe. Mr Bennet has remarked that, notwithstanding the extensive trade carried on in the skins of this animal, it might have been regarded till of late as almost unknown, as no modern naturalist, with the exception of Molina, had seen an entire specimen, either living or dead.[3] That author describes it as a species "of field-rat, in great estimation for the extreme fineness of its wool, if a rich fur as delicate as the silken webs of the garden spiders may be so termed. It is of an ash-grey, and sufficiently long for spinning. The little animal which produces it is six inches long from the nose to the root of the tail, with small pointed ears, a short muzzle, teeth like the house rat, and a tail of moderate length, clothed with delicate fur. It lives in burrows under ground in the open country of the northern provinces of Chili, and is very fond of being in company with others of its species. It feeds upon the roots of various bulbous plants, which grow abundantly in those parts, and produces twice a year five or six young ones. It is so docile and mild in temper, that, if taken into the hands, it neither bites nor tries to escape, but seems to take a pleasure in being caressed. If placed in the bosom, it remains there as still and quiet as if it were in its own nest. The ancient Peruvians, who were far more industrious than the moderns, made of this wool coverlets for beds and valuable stuffs."[4] A more recent observer, Schmidtmeyer, also describes it as "a woolly field-mouse, which lives under ground, and chiefly feeds on wild onions. Its fine fur is well known in Europe; that which comes from Upper Peru is rougher and larger than the chinchilla of Chile, but not always so beautiful in its colour. Great numbers of these animals are caught in the neighbourhood of Coquimbo and Copiapo generally by boys with dogs, and sold to traders, who bring them to Santiago and Valparaiso, from whence they are exported. The Peruvian skins are either brought to Buenos Ayres from the eastern parts of the Andes, or sent to Lima."[5]

A living specimen of the chinchilla was brought to England by Captain Beechy, and presented to the Zoological Society, while, at the same time, an entire skin, rendered valuable by the preservation of the skull (which never exists in the skins of commerce) was presented by Mr Collie, surgeon, to the British Museum. According to Mr Bennet, the slightest inspection of the teeth was sufficient to prove that the species could no longer be associated with the groups in which it had been previously placed, and that it was distinct in character from every other known genus of Rodentia. Geoffroy and Desmarest had previously ranged it with the hamsters (genus *Cricetus*), and Baron Cuvier having never seen its teeth, was uncertain whether it was most allied to the guinea-pigs, the lagomys, or the rats. But the inspection of the specimens above alluded to has shewn that it possesses two incisives and eight molars in each jaw, or twenty teeth in all. The form of the head resembles that of a rabbit; the eyes are full, large, and black; and the ears (in this differing from Molina's description, already quoted) are broad, naked, rounded at the tips, and nearly as long as the head. There are four short toes, with a distinct rudiment of a thumb on the anterior feet; and the posterior are furnished with the same number, three of them long, the middle more produced than the two lateral ones, and the fourth external to the others, and placed far behind. A second specimen has been since added to the collection of the Zoological Society of somewhat larger size and rougher fur.[6]

Order V.—EDENTATA, Cuv.

The term edentate, or toothless, must not be construed literally in relation to the truly singular groups which constitute the present order. The front teeth are absent, but

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[1] *Dict. Class. d'Hist. Nat.* t. iv. p. 248.

[2] *Mammalogie*, p. 357.

[3] *Gardens and Menagerie of the Zoological Society*, vol. i. p. 1.

[4] *Essay on the Natural History of Chili.* Not having either the French or Italian edition at hand, we here use Mr Bennet's quotations from a work which Baron Cuvier has characterized as "fait de memoire en Italie (the author was a native of Chili) et fort suspect en plusieurs endroits."

[5] *Travels into Chile over the Andes.*

[6] *Gardens and Menagerie*, vol. i. p. 9.

Edentata.

the armadillos have both canines and molars,—the latter, indeed, so numerous as to be surpassed only by those of the cetaceous genus *Delphinus*. The osteology of this order is the only portion of their structure with which we are well acquainted, and we owe that knowledge to the beautiful memoir of Baron Cuvier.[1] But we know with what singular fidelity the skeleton, though itself essentially inert, represents, by the form and amalgamation of its parts, the supervening modifications of the more active organs, that is, those of the nervous, sensitive, and digestive systems. In relation to almost all the actions which result from those systems, our present order is not only one of the most widely separate from other Mammalia, but also presents the greatest disparity between several of its own genera, as compared with each other. These genera, it has been observed, though connected together in spite of obvious differences, by several heteroclyte characters, and appearing to be, as it were, the work of a particular conception, are by no means the products of one common country, but almost each group is characteristic of some separate great division of the globe, such as the southern parts of Africa and America, the Indian Archipelago, or New Holland. It is difficult to state any character belonging to the entire order, although the great size of their claws, embracing all the extremity of the toes, and more or less approaching the nature of hoofs, is perhaps among the most prevalent. Their movements may be characterized as slow and inactive. Some climb trees, others dig burrows, while the habits of a few are amphibious. Their food varies in the different genera. None are strictly or fiercely carnivorous, but several devour insects, and shew no distaste for flesh. Many indulge in a herbivorous diet. Baron Cuvier divides the order into three tribes, as follows.

TRIBE 1ST, TARDIGRADA.

We here place those singlar animals of the New World, commonly called sloths,—genus BRADYPUS, Linn. They are distinguished by the shortness of the face, by the cylindrical form of the molars (four on each side above, and three below), and the sharp and lengthened shape of the canines. (See Plate X., figure 3.) The toes, varying as to amount in different species, are incased within the skin as far as the base of the claws, which are long and arched, and in a state of repose are kept bent beneath the palm of the hand, or sole of the foot. The hind feet are articulated obliquely on the leg, and thus act as supports, chiefly by their external margins. "Les phalanges des doigts," says Cuvier, "sont articulées par des ginglymes serrés, et les premières se soudent à un certain âge aux os du métacarpe on du métatarse: ceux-ci finissent par se souder ensemble faute d'usage;"[2] and to this inconvenient (or we should rather say peculiar) structure of the extremities, may be added that of their disproportionate respective lengths. The arm and fore-arm are much longer than the thigh and leg, so that when they walk they are obliged to draw themselves along upon their elbows. The pelvis is so broad, and the thighs are so directed laterally, that the knees cannot approximate. "Ils se tiennent sur les arbres," says Cuvier rightly, for their structure is entirely suited to arboreal habits;—but when he adds, "et n'en quittent un qu'après l'avoir dépouillé de ses feuilles, tant il leur et penible d'en gagner un autre," we must correct the sentiments of the European philosopher by the experience of a practical observer. Mr Waterton states, that as he was one day crossing the river Essequibo, he saw a large two-toed sloth upon the ground. How it came there nobody could tell. Although the trees were not twenty yards from him, he could not make his way even that short distance before the party landed and overtook him. He immediately threw himself upon his back, and gallantly defended himself with his fore-legs. Mr Waterton humanely allowed him to hook himself to a long stick, by which he conveyed him to a high and stately mora tree. This he ascended with great rapidity, and then went off in a lateral direction, by catching hold of the branches of another tree, and so he proceeded towards the heart of the forest, and was soon lost to view. The sloth, in truth, is the most sylvan of quadrupeds. It is produced, it lives, and it dies among trees, and though unequal to cope with John Gilpin in speed, it yields not to his namesake in love of forest scenery. "The sloth," says our author, "is the only known quadruped which spends its whole life from the branches of trees, suspended by his feet. I have paid uncommon attention to him in his native haunts. The monkey and squirrel will seize a branch with their fore feet, and pull themselves up, and rest or run upon it; but the sloth, after seizing it, still remains suspended, and suspended moves along under the branch, till he can lay hold of another. Wherever I have seen him in his native woods, whether at rest, or asleep, or on his travels, I have always observed that he was suspended from the branch of a tree; and when his form and anatomy are considered, it will appear evident that he cannot be at ease in any situation where his body is higher or above his feet."[3] One of the great objects of the creation seems to be to multiply the enjoyments of animal life,—an object which can only be attained by a vast diversity in structure and instinct. In the case of the sloth, as in all other cases, structure and instinct accord, and we may therefore fairly infer, notwithstanding what Buffon and others have *composed* regarding his miserable and degraded existence, that his peculiar mode of life is accompanied by a corresponding share of pleasure and advantage. No animal is organized for wretchedness.

Edentata.

Few species of the genus are as yet distinctly known, and these few offer among themselves a considerable disparity of structure in several important particulars, such as the number of the ribs, and the form of the cranium. The three-toed species, which are furnished with a short tail, form the genus ACHEUS of F. Cuvier. Of these the *aï*, or three-toed sloth (*Brad. tridactylus*, Linn., see Plate X., fig. 2.), is the only animal hitherto supposed to possess nine cervical vertebræ. We have already alluded to the more recent opinion, that in this respect it forms no exception to the usual rule.[4] The *Unau*, or two-toed species (*B. didactylus*, Linn., Ibid., fig. 4), is, according to Cuvier, "un peu moins malheureusement organisé que l'Ai," in other words, something different in its habits of life, renders necessary a less anomalous form. All these animals are believed to be very tenacious of life. They will hang long to the branch of a tree after being mortally wounded. "Delalande aidé de son domestique, a inutilement essayé pendant une demi-heure d'étrangler un Aï avec une corde de la grosseur du doigts; l'animal ne cessait d'étendre et de ramener ses bras en crochets sur la poitrine par intervalles, ce qu'il fit encore pendant plusieurs heures au fond d'un tonneau d'alcohol où on le tint ensuite submergé. Pison avait disséqué vivante une femelle pleine d'unau. Elle se remuait encore en totalité et contractait ses pieds longtemps après l'arrachement du cœur et des viscères."[5] We conclude by observing that sloths are entirely herbivorous, feeding chiefly on leaves, especially those of *Cecropia peltata*.

TRIBE 2D, EFFODENTIA.

In this tribe the muzzle is elongated. The teeth are of the molar kind only (and in some even these are wanting).

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[1] *Ossemens Fossiles*, t. v.

[2] *Règne Animal*, t. i. p. 224.

[3] *Wanderings in South America.*

[4] See our present article, p. 121.

[5] *Dict. Class. d'Hist. Nat.* t. ii. p. 483.

The first generic group is that called Dasypus by Linnæus, which we name armadillo. Their teeth are feeble, simple, and cylindrical, and range in different species from 28 to 68. Their most remarkable character consists in their being covered by a defensive armour, or kind of osseous shell, divided into polygonal scales arranged in numerous transverse bands, covering head, body, and oftentimes the tail. The ears are large, the claws strong, and varying in number with the species. The tongue is smooth, and but slightly extensile. A few scattered hairs occur between the scaly plates, but these creatures can scarcely be said to have any fur. They dig burrows, and live partly on a vegetable regimen, partly on insects, reptiles, worms, and animal remains. Their stomach is simple, and the cœcum is absent. They are all natives of the warmer and temperate parts of America. The females are very prolific.

As we cannot here describe the species, nor even indicate the minor groups into which recent naturalists have divided the original genus, we shall here give a short extract in illustration of their general habits.[1] We quote from Mr Waterton, to whom naturalists are greatly indebted for many interesting elucidations of the history of the rarer animals of South America. "The armadillo burrows in the sand like a rabbit. As it often takes a considerable time to dig him out of his hole, it would be a long and laborious business to attack each hole indiscriminately, without knowing whether the animal were there or not. To prevent disappointment, the Indians carefully examine the mouth of the hole, and put a short stick down it. Now if, on introducing the stick, a number of musquitos come out, the Indian knows to a certainty that the armadillo is in it; and *vice versa*, wherever there are no musquitos in the hole, there is no armadillo. The Indian, having satisfied himself that the armadillo is there, by the musquitos which come out, immediately cuts a long and slender stick, and introduces it into the hole; he carefully observes the line the stick takes, and then sinks a pit in the sand to catch the end of it; this done, he puts it farther into the hole, and digs another pit; and so on, until at last he comes up with the armadillo, which had been making itself a passage in the sand till it had exhausted all its strength through pure exertion. I have been sometimes three quarters of a day in digging out one armadillo, and obliged to sink half a dozen pits, seven feet deep, before I got up to it. The Indians and negroes are very fond of the flesh, but I consider it strong and rank. On laying hold of the armadillo, you must be cautious not to come in contact with his feet; they are armed with sharp claws, and will inflict severe wounds: when not molested, he is harmless and innocent. The armadillo swims well in time of need, but does not go into the water by choice. He is very seldom seen abroad during the day; and when surprised, he is sure to be near the mouth of his hole. Every part of him is well protected by his shell, except his ears. In life, this shell is very limber, so that the animal is enabled to go at full stretch, or roll himself up into a ball, as occasion may require."[2]

We knew little of the actual history of the armadillos, or of their amount of species, till the time of Azara, who describes eight different kinds, one of which (*Das. giganteus*) measures above three feet in length. They were supposed to feed exclusively on vegetable substances, till the Spanish author observed that they were both insectivorous and carnivorous. The direction of their burrows shew that they pursue the ant-heaps, and these laborious insects quickly diminish in their neighbourhood. The great species just named (which belongs to the genus Priodontes of F. Cuvier, distinguished by the great size of its claws, and the enormous number of its teeth,—about 90 in all) feeds on carcasses, and when a human being happens to be buried beyond the usual precincts of the sepulture, and in a district where this animal occurs, the grave is covered by strong double boards, to prevent the disinterment of the body. They also prey on birds and their eggs, as well as on lizards and other reptiles. They are themselves eaten both by native Indians and by Spanish tribes. As an example of the genus we have figured the Encoubert, or six-banded armadillo (*Das. sexcinctus*, Linn., see Plate X., fig. 9), a species distinguished from all the others by possessing a pair of small teeth upon the incisive bone. It measures about a foot and a half in length from the snout to the insertion of the tail. The latter part is round, about half the length of the body, and is ringed only at its base. The cuirass is composed of six or seven moveable bands, formed of large, smooth, rectangular pieces, longer than broad.[3] This animal runs swiftly, and burrows with great ease. It possesses, in spite of its scaly armour, the singular faculty of so pressing and expanding itself upon the surface of the ground, as to become three times broader than high. It is extremely common in Paraguay.

We may here notice a very singular animal of modern discovery, of the natural habits of which our information is as yet extremely scanty, but which partakes of many of the characters of the armadillos. We allude to the *Chlamyphorus truncatus* of Dr Harlan. (See Plate X., figure 1.) It is a subterranean species from Mendoza, in the interior of Chili, so well represented on the plate referred to, as to save us the necessity of descriptive details. The animal was obtained in a living state, but survived in confinement only a few days. Its habits are said to resemble those of the mole, and it is reputed to carry its young beneath the scaly covering of its body. Baron Cuvier states that it has "dix dents partout,"[4] while its original describer mentions only eight on each side (all molars), that is, sixteen in each jaw.[5]

Genus Orycteropus, Geoff. The only known species of this genus is an animal peculiar to Africa, called the Cape ant-eater (*Or. Capensis*). It is of large dimensions, measuring between three and four feet in length, exclusive of the tail, which is nearly two feet long. Its grinders amount to six on each side of both jaws, or twenty-four in all, and are distinguished by a peculiar structure, being in the form of solid cylinders, traversed throughout their length by an infinity of little canals resembling the interior pores of canes. Its habits are nocturnal and subterranean, and its food consists of ants and termites, which it seizes with its long glutinous tongue, after having disarranged their dwellings with its paws. The ant-eaters properly so called, belong to the following genus, and are peculiar to America, so that the species just noticed may be regarded merely as their African representative. Its flesh is used as food, and is indeed held in considerable estimation both by European and Hottentot, notwithstanding the strong odour of formic acid with which it is infected.

Genus Myrmecophaga, Linn. Teeth entirely wanting. Head more or less elongated, and terminated by a slender muzzle and a narrow mouth. Eyes and ears small, the latter rounded. Tongue very long, cylindrical, and capable of extension. Toes (varying in number with the species) always united as far as the base of the claws, which are large and strong. Tail very long, sometimes prehensile and comparatively bare, sometimes covered with lax depending hairs.

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[1] See the *Règne Animal*, t. i. p. 226; Griffith's *Animal Kingdom*, vol. iii. p. 283; F. Cuvier's *Mam. Lithog.*, Azara's *Essai sur l'Hist. Nat. du Paraguay*, t. ii.; Desmarest's *Mammalogie*, p. 366; and the article *Tatou* in the French *Dictionnaires d'Hist. Nat.*

[2] *Wanderings*, p. 183.

[3] A different mode of counting the bands of this and other species has led to some confusion in their synonymy. *D. sexcinctus* and *octodecimcinctus*, Linn. are one and the same, and correspond to the *Tatou poyou* of Azara.

[4] *Règne Animal*, t. i. p. 229.

[5] See *Annals of the New York Lyceum of Natural History*, vol i., and *Zoological Journal*, No. vi.

This genus consists of the true ant-eaters, all of which are natives of South America, and occur chiefly in the countries bounded on the south-east by the Rio de la Plata, and on the north by the Oroonoko. Naturalists are tolerably well acquainted with at least three species. They prey almost exclusively on ants and termites, which they take by means of their long, extensile, gluey tongues, aided, as excavating implements, by their vigorous claws. Like the sloths, there exists among themselves a considerable disparity of structure,—the small two-toed species being provided with strong clavicles, attached to the sternum, while in the larger species these parts are entirely wanting. One of the most notable features of the ant-eaters consists in the lengthened, cylindrical, tunnel-shaped character of the head, which almost resembles that of the long-billed birds, such as snipes and woodcocks. This is caused chiefly by the great prolongation of the jaws, of which the upper (in the species called *Tamandua*) is more than twice the length of the cranium. If these long jaws were to open at the same angle as in most mammiferous animals, the gape or separation of the terminal portions would be proportionally greater than in any other species; but, as it happens, the opening of the mouth is in fact the most restricted with which we are acquainted. This is owing to the jaws being surrounded throughout their entire extent by the skin, there being only a very small terminal mouth, measuring scarcely a fifteenth part of the length of the maxillæ. The muscles of the lower jaw are, moreover, so extremely feeble, as to be almost unable to produce any compression. They seem to collect their food entirely with their tongue, and may be presumed to swallow it without mastication, like the majority of birds and fishes. The ant-eaters, of all the Mammalia, are those of which the temporal fossæ and zygomatic arches are the most effaced. The bones of the nose occupy almost the half of the length of the upper portion of the head. The ribs of these animals are so broad, as to leave scarcely any intermediate space between them.

The great ant-eater (*Myr. jubata*), though low of stature, is an animal of almost gigantic extent, sometimes measuring seven feet from the muzzle to the end of the tail. It has four toes to the anterior feet, and five to the posterior. Its tail is garnished, from base to tip, with very long hair. It seems singular that so large and robust a creature should support itself solely on ants; but we must bear in mind the multitudes of those minute insects which occur in South America. In captivity it may be fed on crumbs of bread, meal, flour and water, &c. A living specimen, brought a good many years ago into Spain, ate readily of raw meat minced, and was said to swallow from four to five pounds a-day.[1] How many ants would be required to equal that amount? This species possesses great strength in its legs and paws, and is said to defend itself successfully against the attacks of the largest feline animals, such as the jaguar and other beasts of prey. It is even held in great dread by the Indians, who however much they may have disabled it, never approach it closely till it is entirely dead. When it seizes an animal with its fore-paws, it hugs it tightly to its body, and retains its grasp so tenaciously as to kill its enemy either by pressure or starvation. It does not climb trees.

The species known under the name of Tamandua (*Myr. tamandua*, Cuv., *M. tetradactyla* and *tridactyla*, Linn.), is not more than half the size of the preceding, and differs in its prehensile and almost naked tail, by which it is assisted in climbing trees. Azara supposed that, in addition to the usual insect food, this species eats wild bees and honey. It smells strongly of musk. The little ant-eater (*M. didactyla*, Linn., see Plate X., figures 5 and 8) is rather an elegant animal. Its body measures little more in length than six inches, and, besides the great disparity of size, it is distinguished from the two preceding species by having only two claws to the fore feet and four to the hinder ones. It is covered by a beautiful soft fur, of a very pale yellowish-brown colour. It inhabits the woods of Guyana and Brazil, dwelling habitually on trees, and preying on ants and other insects.

GENUS MANIS, Linn. In this genus also the teeth are entirely wanting. The body is extremely elongated, low upon the legs, and covered by strong corneous scales. The muzzle is very long, the mouth small and terminal, the tongue of remarkable length, round and extensile. All the feet have five toes, armed with strong talons. The tail is very long, covered with scales, and as broad at its base as the termination of the body.

The entire range of the animal kingdom scarcely presents us with species of a more marked and peculiar aspect than the manis tribe or *pangolins*. Instead of hair they are covered by a scaly armour, composed of triangular plates, placed upon each other like slates or tiles; and this remarkable character, combined with their attenuated form, gives them so much the appearance of reptiles, that they are often designated as *scaly lizards*. (See Plate X., figures 6 and 7.) We possess no very detailed knowledge of their natural history. They seem to be inoffensive creatures, feeding, like the ant-eater, on insects, especially ants, which they collect by thrusting their long insidious tongue into the dwellings of these industrious labourers. Three species are described by systematic writers, and of these one inhabits continental India, another occurs in Java, and a third is native to Senegal and the coast of Guinea.

TRIBE 3D, MONOTREMA.

The term by which this tribe is designated was first bestowed by Geoffroy St Hilaire, and is now very generally adopted by naturalists. It applies to a small number of species discovered in New Holland in comparatively recent times, and characterized by a general organization, certainly conformable to that of other mammalia, but with modifications so remarkable and anomalous, that their true position in the animal kingdom (the very class to which they belong), is still a disputed point. The apparent absence of mammæ, and their supposed oviparous nature, were these two circumstances satisfactorily ascertained, would either remove them from the ordinary class of quadrupeds, or render necessary an alteration in the technical definition of that class. In our present tribe only two genera are as yet included, viz. ECHIDNA and ORNITHORHYNCHUS. Latreille was of opinion that these should form two distinct orders, an arrangement which has not been adopted, but which possesses the advantage of shewing that they greatly differ from each other,—an inference not deducible from Sir Everard Home's mode of combining them in a single genus. Shaw placed Echidna with the ant-eaters, and as connecting these with the porcupines; while he expressed his opinion that Ornithorynchus (his genus *Platypus*), should follow Myrmecophaga. This arrangement, in fact, approaches very close to that adopted by Baron Cuvier.

The monotremous tribes exhibit several peculiarities in their osteological structure, by which they are further allied to the class of birds. Such, for example, is a kind of clavicle common to both shoulders, placed in front of the ordinary clavicle, and analogous to the furcula of the feathered tribes. Besides the five claws on each foot, the males bear a spur on their hind legs, resembling that of a cock, but pierced by a canal capable of transmitting a liquid of a venomous or inflammatory quality, secreted by a peculiar gland.[1] But however anomalous these and other characters may be, when we consider their quadrupedal form, their hairy covering, their lungs freely suspended, the existence of a diaphragm, the rudiments of teeth, and the general agreement of the skeleton with that of other mammiferous animals, we can scarcely hesitate as to the class to which they belong.[2] Their agreements with the Mammalia are numerous and striking, and deduced from the most important organs, while their disagreements are few, and deduced for the most part from characters not of the highest value. We shall conclude these meagre generalities with the words of Baron Cuvier: "Avec les formes extérieures et le poil des mammifères; avec leur circulation, leur cerveau, leurs organes des sens, et une grande partie de leurs organes du mouvement; avec le bassin des Didelphes, les Monotremes ressemblent à beaucoup d'égards, aux oiseaux et aux reptiles par leur épaules et par les organes de la generation; ils manquent de mamelles et paraissent assez vraisemblablement produire des œufs ou quelque chose d'equivalent, au lieu de mettre au jour des petits vivans. Ils semblent vouloir échapper à nos classifications par leur ostéologie comme par leurs autres rapports. On ne peut comparer celle de leur tête à celle d'aucun des ordres de Mammifères; cependant c'est une vraie tête de Mammifère et non d'ovipare d'aucune classe."[3]

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[1] Shaw's *General Zoology*, vol. i. p. 168.

GENUS ECHIDNA, Cuv. Teeth entirely wanting, but their functions partly supplied by several rows of small spines upon the palate, directed backwards. Muzzle long, slender, terminated by a small mouth, containing an extensile tongue. Body short and rounded, covered by many strong sharp spines. Legs short, each foot furnished with five strong claws, fit for digging. Tail very short.

Only two species of this genus have been as yet discovered,—the *E. hystrix*, which occurs in the vicinity of Port Jackson, and is almost entirely covered by strong spines, and the *E. setosa*, a native of Van Diemen's Land and the islands in Bass's Straits, characterized by fewer species, and a more ample coat of hair. (See Plate XI., figure 1.) Some observers incline to consider them as varieties of the same species, resulting from a difference in age.[4] Both animals are nearly of the size, and somewhat of the aspect, of a hedgehog. They feed on insects, and burrow under ground with great strength and celerity, their feet and claws being admirably adapted to subterranean purposes. It is even said that they will make their way beneath a wall, or under a pretty strong pavement. During these exertions their bodies become greatly lengthened, so as to present a very different appearance from that of their ordinary state. They keep much under ground during dry weather, and move about chiefly during the rains. They are capable of supporting a long continued abstinence, and seem subject to a kind of numbness or peculiar stiffness (*engourdissement*), which will sometimes continue for upwards of eighty hours, and is frequently renewed when they are retained in captivity.[5]

GENUS ORNITHORHYNCHUS, Blumenbach. *Platypus*, Shaw. This genus differs from the preceding, in having two fibrous molar teeth placed in the gums on each side of both jaws. The muzzle is prolonged into a broadish flattened beak, greatly resembling that of a duck. The head is small and round, with minute eyes, and no external ears. The nostrils are round, close to each other, and placed near the extremity of the upper mandible or jaw. The tongue is in some measure double,—there being one within the beak, beset with villosities, and bearing another at its base, of a thicker form, with two small fleshy anterior points. The legs are very short, directed laterally, the anterior and posterior very distant from each other, owing to the comparatively lengthened form of the body. Each foot has five toes, those of the anterior extremities of nearly equal size, slender, separate, furnished with flattened nails, united by a peculiar membrane which projects beneath them; the posterior toes united as far as the nails. Tail rather short, broad at the base. The body is covered with hair.

Of this very singular genus it does not appear that more than a single species has as yet been ascertained,[6]—the *Ornithorhynchus paradoxus* of modern writers, first described by Dr Shaw under the name of *Duck-billed Platypus*.[7] It is an animal of a very peculiar aspect (see Plate XI., figure 2), of amphibious habits, and a native of New Holland, where it inhabits marshes, and the banks of rivers, especially in the neighbourhood of Port Jackson. The general belief is, that it lays eggs. We think, however, that that fact has as yet been rather inferred than demonstrated; and it is certainly singular that it should not have been proved in those districts where the species is so often met with, and where so extraordinary a circumstance must have excited a corresponding degree of curiosity and attention. The following detailed particulars were published some time ago in an Italian periodical, but without any indication of the source from which they were derived: "The ornithorhynchus inhabits the marshes of New Holland. It forms, among beds of reeds by the water-side, a nest composed of hair or wool, and intermingled roots, in which it deposits two white eggs, smaller than those of our domestic poultry; on these it sits a long time, hatching them like a bird, and refusing to leave them unless threatened by a very formidable foe. It appears that during all this time it eats neither seeds nor herbs, but contents itself with slime or mud; at least nothing more is found within it. When the ornithorhynchus plunges under water, it remains but a short time submerged, and comes soon to the surface, shaking its head like a duck. It walks, or rather creeps, along the margins of the marshes with considerable quickness; its movements are prompt, and its sight so excellent as to render its capture difficult. It usually employs only one nostril in respiration. It scratches its head and neck, like a dog, with one of its hind legs. It attempts to bite when taken, but can inflict no injury, owing to its soft and feeble beak. The male alone is armed with a spur upon the hinder legs, and he employs that weapon against his aggressors. The wound which he inflicts produces inflammation and a violent pain, but there is no instance of its having ever occasioned death."[1] There is an appearance of truth in the circumstantial mode in which the preceding details are narrated, and we therefore regret the more that they should have appeared anonymously. The testimony borne to the oviparous nature of the animal in question accords with the reported belief of the natives, and with the researches of Hill and Jamison. "The female," says the last named observer, "is oviparous, and lives in burrows in the ground, so that it is seldom seen either on shore or in the water. The males are seen in numbers throughout our winter months only, floating and diving in all our large rivers; but they cannot continue long under water. I had one drowned by having been left during the night in a large tub of water. I have found no other substance in their stomachs than *small fish and fry*. They are very shy, and avoid the shot by diving, and afterwards rising at a considerable distance."[2]

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[1] "I cannot," says Sir John Jamison, "avoid relating to you an extraordinary peculiarity which I have lately discovered in the Ornithorhynchus paradoxus. The male of this wonderful animal is provided with spurs on the hind feet or legs, like a cock. The spur is situated over a cyst of venomous fluid, and has a tube or cannula up its centre, through which the animal can, like a serpent, force the poison when it inflicts its wound. I wounded one with small shot; and, on my overseer's taking it out of the water, it struck its spurs into the palm and back of his right hand with such force, and retained them in with such strength, that they could not be withdrawn until it was killed. The hand instantly swelled to a prodigious bulk; and the inflammation having rapidly extended to the shoulder, he was in a few minutes threatened with locked jaw, and exhibited all the symptoms of a person bitten by a venomous snake. The pain from the first was insupportable, and cold sweats and sickness of stomach took place so alarmingly, that I found it necessary, besides the external application of oil and vinegar, to administer large quantities of the volatile alkali with opium, which I really think preserved his life."—Extract from letter dated Regentville, New South Wales, September 10. 1816, published in *Linn. Trans.*, vol. xii. p. 584. See also Dr Knox's *Observations on the Anatomy of the Ornithorhynchus paradoxus*, in *Memoirs of the Wernerian Society* (for 1823–4), vol. v. p. 26 and p. 144.

[2] See De Blainville's *Dissertation sur la place que la famille des Ornithorhynches et des Echidnés doit occuper dans les series naturelles.*

[3] *Ossemens fossiles*, t. v.

[4] "L'échidné, dont on fait deux espèces, suivant que les piquans sont plus ou moins garnis de poils, est vraiment unique."—Lesson's *Manuel de Mammalogie*, p. 318.

[5] See *Zoologie de la Coquille*, p. 134, et seq.

[6] In this opinion we coincide with Oken, Meckel, and Geoffroy St Hilaire. Desmarest, Macgillivray, Vander Hoeven, Peron and Lesueur, and other writers, have described what they regard as one or more species distinct from the common kind. We apprehend that these authors, in the absence of an extensive series of specimens, have attached too much importance to certain *individual* variations.

[7] *Naturalist's Miscellany*, pl. 385.

ORDER VI.—PACHYDERMATA.

In entering upon the consideration of this interesting order, we may remind the reader that all the terrestrial Mammalia are divisible into two great secondary groups, the unguiculated or nailed quadrupeds, and the ungulated or hoofed quadrupeds. The former series may be said to terminate with the Edentata, which themselves approach the ungulated tribes in the great size of their claws, and the hoof-like fashion in which these embrace the extremities of the toes. They still, however, possess the faculty of being bent, or otherwise varied in their motion, for the purposes of seizure, excavation, &c. It is the absence of that faculty which characterizes the hoofed animals properly so called; they want the clavicle, and their anterior extremities are always in a state of pronation, being available only for the purposes of support and of locomotion, but not for collecting their food, or for any other kind of manipulation. They all browse on vegetable substances, and their bodily forms, as well as their modes of life, are less varied than those of the unguiculated orders.

The great ungulated or hoofed division is itself partitioned into two groups, one of which consists of the ruminating tribes (order PECORA or RUMINANTIA), and the other of certain thick-skinned genera, called PACHYDERMATA,—our present order. Of these two orders it will be readily perceived that the former is established upon organic peculiarities of the highest importance, and is therefore in a great degree natural and well composed, while the constituents of the latter agree principally in the negative character of not being ruminant, and exhibit among themselves so great a range and diversity of structure and character, as to present a much less natural combination. We find, accordingly, in examining the different genera, that their toes vary (externally) from one to three, four, and five; that their teeth are sometimes of three kinds, sometimes of only two; that their skin, generally bare, is occasionally covered by close or even shaggy hair; that their stomach, in some cases simple, is in others divided into several pouches; that the size of certain species is small, while that of others attains to the most gigantic dimensions; and that while certain minor groups seem nearly allied to the ruminants, others are broadly distinguished by numerous anomalies of organization, some of which point them out as among the most remarkable species of the animal kingdom. In a word, the pachydermatous order consists of the small sized living Daman, and the gigantic and now extinguished Mastodon,—of the swift and slender limbed horse, and the short-legged sluggish rhinoceros,—of the savage boar, and mild-eyed elephant. The great differences which exist in the genera now named have occasioned the grouping of this order into several families, which some authors are inclined to view rather in the light of distinct orders.[3] We certainly think that the removal of the genus Equus (which Illiger and others have classed as a separate order under the title of SOLIDUNGULA) would enable us to simplify our definition of the pachydermous tribes.

FAMILY 1ST.—PROBOSCIDEA.

This family includes of living creatures (and with the fossil species we are not concerned) the genus ELEPHAS alone. The skeleton exhibits five complete toes, but so encrusted in a callous skin which surrounds the foot, that only the nails are visible, attached, as it were, to the margins of a seeming hoof. The canine teeth, and incisives, properly so called, are wanting, but in the incisive bones are implanted a pair of tusks, projecting much beyond the mouth, and sometimes attaining an enormous size. The necessary dimensions of the alveoli of these peculiar teeth, as Baron Cuvier has remarked, render the upper jaw so high, and so shorten the bones of the nose, that the nostrils, in the skeleton, occur towards the upper portion of the face, although in the living animal they are prolonged under the form of a long, gradually attenuated, cylindrical, trunk or proboscis, composed of several thousand small muscles, so variously interlaced as to produce a great diversity of motion, endowed with an exquisite sense of touch, and terminated by a small finger-formed appendage. By means of this admirable organ the elephant is possessed of almost as much address as the ape receives from the human-like structure of its hand. Its exquisite uses are so frequently exhibited in menageries, that we need scarcely expatiate upon the subject. The head, though of enormous size, is rendered comparatively light by the cellular structure of a large portion of the cranium. There are no incisive teeth in the lower jaw; the grinders are two on both sides of each jaw; making the total number ten, including the tusks. The stomach is simple, the cœcum enormous, the mammæ only two, their position pectoral.[4]

As the GENUS ELEPHAS contains all the living species of the family, the preceding characteristics may be regarded as generic. The distinctive character of the teeth consists in the molars being composed of a certain number of vertical plates, each formed of an osseous substance, enveloped by enamel, and connected together by a third or cortical matter. These teeth succeed each other not vertically, as the second molars of the human race succeed the milk-teeth, but from behind forwards, in such a manner that in proportion as one grinder becomes used it is pushed forward by its successor; and thus there is sometimes two, sometimes only one on each side. The first teeth have few plates, the succeeding ones a greater number; and the molars are said to be sometimes changed as often as eight times, while the tusks or great incisives are only once renewed. There are only two species known to naturalists of these gigantic creatures.

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[1] *Anthologia* (di Firenze), t. xxiv. p. 305.

[2] *Linn. Trans.* vol. xii. p. 385. An interesting account of a living ornithorhynchus, in captivity, was published by Mr George Bennet, in one of the "Annuals."

[3] See *Dict. Class. d'Hist. Nat.* t. xii. p. 579.

[4] *Règne Animal*, t. i. p. 238.

The African elephant (*G. Africanus*) is easily distinguished from the Asiatic species by his rounder head, more convex forehead, much larger ears, and the lozenge-marked surface of his grinders. His tusks are also longer, and those of his female are described as equally great with his own, whereas the female of the Asiatic elephant has very small tusks. He inhabits a wide extent of Africa from Senegal to the Cape, and abounds in the forests of the interior. That the African elephant has not in modern times been rendered serviceable to man, we cannot think arises from any defect in the wisdom or docility of his disposition, but rather from a difference in the social and political conditions of the human tribes of Africa, and their inferior civilization. It is known that the ancient Carthaginians made use of elephants, which, so far as our information extends, there is no reason to believe were otherwise than of African origin; in like manner as the Asiatic variety was used by Porus and the Indian kings. It is not yet clearly ascertained whether the individuals of the eastern shores of Africa are specifically the same as those of the interior and western districts, or whether they do not exhibit a closer approximation to the Asiatic species. We may observe, that the size of both the African and eastern elephant has been much exaggerated. Dr Hill, for example, asserts that when full grown they will measure from seventeen to twenty feet in height. One-half of the latter dimension is probably nearer the truth, even for an individual of more than usual size, and twelve feet may be stated as an extreme height. The African, however, are alleged (by travellers though not by systematic writers) to be larger than those of Asia. Major Denham, for example, while journeying to the Schad, saw elephants so enormous that he calculated their height at sixteen feet. These, however, he had no opportunity of measuring; but another which was killed in his presence was found to be nine feet six inches from the foot to the hip-bone, and three feet from the latter to the back; that is, twelve feet and a half in all, or more than twice the height of the tallest races of mankind. When we consider, that even in proportion to its height, the elephant is an animal of enormous bulk, and of the most massive proportions, we may conceive what an enormous mass of flesh and bone its rugous coat must usually contain. A large individual weighs from six to seven thousand pounds, and it may easily be imagined that when travelling through the forest with any special object in view, he must force his way through all intervening obstacles more after the manner of a modern locomotive engine, than of any mere animal force of which we have an accustomed conception.

> "Trampling his path through wood and brake,
> And canes which crackling fall before his way,
> And tassel-grass, whose silvery feathers play,
> O'ertopping the young trees,
> On comes the elephant to slake
> His thirst at noon in yon pellucid springs.
> Lo! from his trunk upturn'd, aloft he flings
> The grateful shower; and now,
> Plucking the broad-leav'd bough
> Of yonder plume, with waving motion slow,
> Fanning the languid air,
> He waves it to and fro."[1]

Of the Asiatic elephants (*Eleph. Indicus*, see Plate XI., fig. 3) those of Ceylon are among the most celebrated. Indeed, the torrid zone seems the most favourable for the production of the largest races; for although elephants occur along the coast of Malabar as far north as the territories of Coorgah Rajah, these, according to Mr Corse (Scott) are inferior to the breed from Ceylon. Those of China, where they seem to be used rather as an appendage of imperial greatness than as beasts of burden, are described as smaller than those of more southern regions, and of a lighter hue. A few are, however, said to have bred to the northward of the tropic; and we may add, that elephants appear to have been very anciently known even in remote parts of the Chinese empire.[2] As Kublai Khan, one of the conquering heroes of the thirteenth century, subdued Ava and other southern provinces, where elephants are known to have abounded, and where they were opposed to his armies in battle, it is probable that he then added those gigantic and imposing animals to his establishment, and conveyed them to the more northern parts of his great Tartarian empire, which included a large portion of what we now designate by the name of China. A few are still kept by the emperors of the reigning dynasty.[3]

It is to the Asiatic species that most of the anecdotes apply, as recorded in our systematic works and books of travels.[4] Although generally regarded as the "wisest of beasts," it is alleged by some to owe much of its apparent sagacity to that admirable instrument its proboscis, by which it is enabled to perform many actions which the canine race, though probably equal in wisdom, cannot achieve in consequence of their different, if not more defective, organization. "Après," says Baron Cuvier, "les avoir étudiés long-temps, nous n'avons pas trouvé qu'elle (l'intelligence) surpassât celle du chien ni de plusieurs autres carnassiers."[5] Still we think it is demonstrable both from ancient record and modern observation, that the elephant is most highly gifted for an irrational being, and that it generally retains its finer natural instincts even in conjunction with those artificial acquirements which in several other sagacious species seem to deaden or destroy the influence of pure instinctive feeling.

We have already stated our opinion that the size of the elephant is usually exaggerated. Mr Scott of Sinton, whose authority is frequently quoted, and deservedly valued on such points, has stated, in relation to the Asiatic species, that he never heard of more than a single instance of its exceeding the height of ten feet. The following are the proportions which he gives of a fine male belonging to the Vizier of Oude:—

	Feet.	Inches.
From foot to foot over the shoulder, . . .	22	10½
From the top of the shoulder, perpendicular height, ...	10	6
From the top of the head when set up, . .	12	2
From the front of the face, to the insertion of the tail, ...	15	11

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[1] Southey's *Curse of Kehama.*

[2] See various passages in Marsden's edition of the *Travels of Marco Polo.*

[3] Bell's *Travels*, vol. ii. p. 25; Van Braam's *Voyage en Chine*, t. i. p. 280.

[4] As our restricted space prohibits an ampler exposition, we beg to refer the reader to a very accessible volume (in the *Library of Entertaining Knowledge*) entitled *The Menageries*, vol. ii., where a complete account is given of the ancient and modern history of elephants.

[5] *Règne Animal*, t. i. p. 239.

Nothing, indeed, is more deceptive than the dimensions of an animal which, obviously exceeding in size whatever living creature we have been previously accustomed to, has yet been unsubjected to actual measurement, for our astonishment magnifies the real size. Thus a celebrated elephant belonging to the Nabob of Dacca, which was generally reported to be fourteen feet high, and which even Mr Scott's practised eye estimated at twelve, was found by measurement not to exceed ten feet. Those from Pegu and Ava (as well as the Ceylonese) are, however, of greater size than those of Hindostan. There is the skeleton of an elephant in the museum of St Petersburgh, presented by the King of Persia to the Czar Peter, which measures above sixteen feet in height, but we have no doubt that some portion of this prodigious stature is owing to the mode in which the bones have been articulated in the *setting up*, and the more or less natural curvature of the spine. A new born elephant usually measures about thirty-five inches high, and he is said to grow eleven inches the first year, eight the second, five the fifth, three and a half the sixth, and two and a half in the seventh year. He takes from twenty to thirty years to attain his full growth, and has been alleged to live for a couple of centuries. There are authentic instances of elephants having been kept in a domestic state for a hundred and thirty years. The female is capable of breeding after her fifteenth year. She produces a single young one at a birth, after a gestation of from twenty-two to twenty-three months.

Elephants in this country are usually fed on hay and carrots, and the quantity of food which they consume is enormous. Those of the Emperor Akbar had each a daily allowance of 200 pounds in weight, with an additional supply of ten pounds of sugar, besides rice, milk, and pepper; and during the sugar-cane season each was provided daily with 300 canes. The Mogul princes are known to have kept up their stud of elephants at a vast expense; and according to Pliny, even the Romans, a people so addicted to extravagance, found the sustaining of the Carthaginian elephants captured by Metellus so costly, that they were afterwards slain in the circus. Yet, according to Ælian's account, less rigid economy prevailed in the days of Germanicus. His elephants were exhibited in the arena, reposing on splendid couches, adorned with the richest tapestry. Tables of ivory and cedar-wood were placed before them, and on these their viands were presented in vessels of gold and silver. They danced to the sound of "flutes and soft recorders," or moved about the theatre in measured and harmonious steps, scattering around them the freshest and the choicest flowers. Arrian mentions an elephant which played on symbols, one being fastened to each knee, and another held by his proboscis, while his unwieldy companions danced in a circle, keeping time with the greatest exactness.

The general use of gunpowder in the practice of war, and the application of steam to machinery, have greatly superseded the employment of this gigantic living engine for the purposes of the human race, although it is still extensively used as a beast of burden in the East. In regard to the pecuniary value of the elephant, Mr Forbes informs us that a common price is from 5000 to 6000 rupees, but that he has seen one valued at 20,000.[1] We must now terminate our miscellaneous notices of this interesting genus.[2]

FAMILY II.—PACHYDERMATA PROPER.

In the majority of this family the three sorts of teeth exist together, and the number of toes ranges from two to four. Those in which the toes are of an even number have their feet in a measure cloven, and approach the ruminants both in the structure of the skeleton, and the complicated form of the stomach.

GENUS HIPPOPOTAMUS, Linn. Incisives $\frac{4}{4}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; $= 36$.[3] Body very bulky, legs proportionally short, the feet with four toes terminated by small hoofs. Lower incisives cylindrical, and directed obliquely forwards. Skin extremely thick, and hairless.

Only one species of this genus is distinctly known to naturalists, the *Hippopotamus amphibius* of systematic writers.[4] Next to the elephant and rhinoceros this is probably the most bulky land animal with which we are acquainted. It is peculiar to Africa, where it inhabits the fresh waters of the central and southern portions of that sultry continent. It appears to have formerly existed in Lower Egypt, but has long since disappeared from that district. It is, however, well known in Abyssinia. Mr Salt had no sooner reached the banks of the Tacazze, a tributary of the Nile, than his attention was roused by the cry of his attendants of "Gomari! Gomari!" the native title of the hippopotamus; but he at that time succeeded in obtaining only a momentary glance, which sufficed to shew that its action somewhat resembled the rolling of a grampus in the sea. The river was about fifty yards across, and between its fords, at the place alluded to, there are pools of almost immeasurable depth, resembling the wild and beautiful mountain tarns of the north of England, and in these the amphibious giants love to dwell. Mr Salt and his party stationed themselves on a high overhanging rock which commanded a deep translucent pool, and they did not remain long before a hippopotamus rose to the surface at a distance of twenty yards. He came up very confidently, raising his enormous head above the water with a violent snort. The muskets were instantly discharged, their contents seemed to strike directly on the forehead, on which he turned round his head with an angry scowl, and making a sudden plunge, descended to the bottom, with a peculiar noise between a grunt and a roar. The sportsmen for a time entertained the hope that he was killed, but he ere long rose again close to the same spot, apparently not much concerned at what had happened, but with somewhat greater caution than before. The guns were again discharged, but as ineffectually as before; and although some of the party continued firing at every one that made his appearance, they were by no means certain that the slightest impression was produced. This they attributed to their having used *leaden* balls, which are too soft for such almost impenetrable skulls. One of the most interesting parts of the amusement consisted in witnessing the perfect ease with which these huge creatures quietly descended to the bottom, for the water being exceedingly clear, they were distinctly perceptible at least twenty feet beneath the surface. They are able to remain five or six minutes at a time under the water.[5] The flesh of the hippopotamus is used as food by many of the African tribes; its skin is also employed for a variety of purposes, and its teeth yield an ivory of great value.

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[1] *Oriental Memoirs.*

[2] In addition to the works already quoted, we have in this as in some other parts of our present treatise, availed ourselves of the natural history sketches contained in various volumes of the *Edinburgh Cabinet Library.*

[3] An additional molar is sometimes found on each side of the upper jaw, but it seems of a temporary nature.

[4] M. Desmoulins regards the species of Senegal as distinct from that of the southern extremity of Africa.

[5] Salt's *Voyage to Abyssinia*, p. 345.

Genus Sus, Linn. Incisives $\frac{4}{6}$ or $\frac{6}{6}$, canines, $\frac{1-1}{1-1}$, molars, $\frac{7-7}{7-7}$; $= 42$ or 44. All the feet furnished with four toes, of which two are anterior or intermediate, and of larger size, and two are lateral or posterior, and so short as scarcely to touch the ground. The lower incisives always project forwards, and the canine teeth, even those of the upper jaw, likewise project and curve upwards. The snout is lengthened, and truncated at the point.

The wild boar (*Sus aper*), the supposed origin of our domestic breeds of swine, occurs in many parts of Europe, Asia, Africa, and the islands of the Indian Sea. Its body is of a brownish-black colour, covered with bristles, which are hard and stiff, especially along the spine. It is an animal of great strength, and considerable activity; but its dimensions though large, probably never exceed those of an overgrown individual of the domestic breed. Wherever the boar occurs in a state of nature, he is found in moist and shady situations, generally well wooded, and for the most part not far distant from streams and marshes. He prefers even cultivated grounds, with all the dangerous consequences likely to result from such localities, to dry or open tracts of weather-beaten barrenness. However fierce in self-defence, when attacked in some favourite place of strength, or irritated during the rutting season, when his passions are inflamed, his natural tastes are almost entirely herbivorous. Buffon, however, states that they have been seen eating horse flesh; and the skin of deer, and the claws of birds, have been sometimes found within them. Desmarest asserts that they devour the smaller kinds of game, such as leverets and partridges, and are very fond of eggs. Their habits are rather nocturnal, at least they are frequently observed to quit their coverts during the evening twilight, and when they hold their lair in the vicinity of human cultivation, they often do great damage by turning up the soil in long straight deep furrows, in search of roots or grain. By means of their delicate perception of the sense of touch and smell, they discover and disinter many low growing plants, half sunk beneath the soil, and hence probably their desire to dwell in moist and sombre places where, amid "a boundless contiguity of shade," their natural powers are more easily and efficiently exerted. They continue to increase in size and strength for four or five years, and are said to live for about thirty years. It is when they have nearly attained maturity, that they afford the most exciting and dangerous occupation to the sportsman. A strong boar will then continue to run for a long time, and finally make the most vigorous and determined self-defence. An experienced boar exhibits considerable intelligence in avoiding his enemies, although the strong scent which emanates from him, especially in a state of irritation, renders his eventual escape from the dogs extremely doubtful. In his revenge also, there is said to be less of blind and indiscriminate fury than might be expected from his coarsely savage aspect; for even when harassed beyond the hope of life, and about to be torn to pieces by the insatiate hounds, should he receive a ball from the huntsman's rifle, he has been known to turn upon his dread pursuers, to break through the bellowing pack, and to single out and assault with savage ire his human persecutor.[1]

The wild boar is among the fiercest of the animals of India. It there inhabits chiefly the woods and jungles; but when the grain is nearly ripe, it occasions great damage in corn fields, and still greater among sugar plantations. In eastern countries it is spread over a vast extent of territory, and exists in great abundance in the Archipelago of the Papuas, to the north of the Moluccas, and the westward of New Guinea. It would even appear that there are two wild species in the Celebes (besides *Sus Babyrussa*), and some writers are of opinion that there exists in the Indian and Chinese dominions a species distinct from the wild boar of Europe, and the more probable source from which the Siamese breed, and that of China, have been derived.

We cannot here enter into a detailed history of our numerous cultivated breeds. With a repulsive aspect, an ungraceful form, the most sensual habits, and a ferocity of disposition not seldom approaching to that of the carnivorous tribes, the domestic hog is nevertheless one of the most useful of quadrupeds. If the value of a benefit depends in a great measure on its universality, this despised animal may indeed claim a higher rank than many of a loftier nature; for one of the most singular circumstances in its history is the immense extent of its distribution, more specially in far removed and isolated spots, inhabited by semi-barbarian people, to whom the wild species is utterly unknown. The South Sea Islands, for example, on their discovery by Europeans, were found to be well stocked with a small, black, short-legged hog; and the traditionary belief of the human natives, bore that they were as anciently descended as themselves. The hog, in fact, is in these islands the principal quadruped, and is of all others the most carefully cultivated. The bread-fruit tree, either in form of a sour paste, or in its natural condition, constitutes its favourite food, and its additional choice of yams, eddoes, and other nutritive vegetables, rendersits flesh most juicy and delicious,—its fat, though rich, being at the same time (so says Foster) not less delicate and agreeable than the finest butter. Before our missionary labours had proved so signally successful in those once forlorn and benighted regions, by substituting the mild spirit of Christianity for the sanguinary forms of a delusive and degrading worship, the Otaheitans, and other South Sea islanders, were in the habit of presenting roasted pigs at the *morais*, as the most savoury and acceptible offering to their deities which they could bestow. Hogs are now abundant in America. They were not, however, indigenous to the New World, but were transported thither by the Spaniards, soon after the discovery and conquest by that nation of the western regions. China is famous for its pigs, and throughout most of the provinces is much more abundant than mutton. Indeed the powerful and prevailing love of the former viand has even been assigned by a philosophical historian as a principal reason for the rejection by the subjects of the celestial empire, of the laws and religion of Mahomet.[2]

Of animals allied to the boar we may name the *Sus larvatus*, a species which occurs in Madagascar and Southern Africa, and the *Sus Babyrussa* (see Plate XI., figure 4), a native of the Indian Archipelago, distinguished by its longer and more slender limbs, and the extraordinary length of its upturned and greatly curved tusks. The genus **Phacochœrus**, F. Cuvier, has only two incisives in the upper jaw, and even these are often wanting, though their vestiges are sometimes found beneath the gums. It is also characterized by a large and fleshy lobe on either cheek. The species (supposed to be two in number, if that described by Ruppel is really distinct) are fierce and savage animals, which, when attacked, become extremely furious, and rushing on their enemies with great force and swiftness, occasionally inflict the most desperate and sometimes fatal wounds. The genus **Dycoteles** of Cuvier, has four incisives above, six below, with two canines and six molars in each jaw. The species differ from all the preceding porcine groups in the canines being directed in the ordinary

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[1] *Quarterly Journal of Agriculture*, vol. ii. p. 875. An account is given of the different domestic breeds in vol. iii. p. 35, of the same work.

[2] Ibid. vol. ii. p. 877.

Pachydermata.

Pachydermata.

manner, in there being only three toes to the hinder feet, and in the tail being tubercular. These animals, commonly called *peccaries*, are native to South America, where there are two species, the collared peccary (*D. torquatus*), and the white-lipped peccary (*D. labiatus*). The former inhabits the Atlantic coasts of the New World from Guyana to Paraguay, the latter occurs in parts of the same extensive range, and is sometimes met with in vast flocks. It is easily tamed, and its flesh is good to eat. Prior to the practical researches of Azara, both species seem to have been confounded under the title of *Sus Tajassu*, Linn.

GENUS RHINOCEROS, Linn. The number of teeth in this genus differs according to the species. Each foot is divided into three toes. The bones of the nose, which are very thick, and united into a hollow arch, bear one or more horns, which adhere to the skin, and are composed of a fibrous substance, resembling a mass of agglutinated hairs.

The species, of which four or five are known to naturalists, are of a dull and heavy aspect, and of much more restricted capacity than the elephant. Though inferior also in size to that sagacious creature, they are yet of sufficiently gigantic dimensions to form a very imposing feature in zoology. Their senses of sight and touch are said to be rather defective; those of smell and hearing more acute. A young rhinoceros, kept in the Garden of Plants, in Paris, was habitually gentle, obedient to his keepers, and extremely sensible of kindness. He exhibited, however, at times the most violent paroxysms of rage, during which it was necessary to keep beyond " the pale of such contention," as it would have been but poor comfort to those whom he might have gored, to be informed that his ordinary proceedings were entirely innocuous. He was usually mitigated by a liberal supply of bread and fruit, and as soon as he saw those who were in the habit of feeding him, he would stretch his muzzle towards them, open his mouth, and extend his tongue.

The preceding observations apply to the species of continental India (*Rhinoceros Indicus*, Cuv., see Plate XI., fig. 8), which, besides twenty-eight molars, has two strong incisive teeth in each jaw, two others of a smaller size between the lower incisives, and one still smaller on each incisor of the upper jaw. It has only one horn, and its skin forms deep folds behind and across the shoulders, and before and across the thighs. " The power of this species is frequently displayed to a surprising degree when hunting it. A few years ago, a party of Europeans, with their native attendants and elephants, when out on the dangerous sport of hunting these animals, met with a herd of seven of them, led, as it appeared, by one larger and stronger than the rest. When the large rhinoceros charged the hunters, the leading elephants, instead of using their tusks or weapons, which, in ordinary cases, they are ready enough to do, wheeled round, and received the blow of the rhinoceros on the posteriors. The blow brought them immediately to the ground with their riders, and as soon as they had risen, the brute was again ready, and again brought them down, and in this manner did the combat continue until four of the seven were killed, when the rest made good their retreat.[1]

The rhinoceros of Java (*Rh. Javanus*, Cuv.) is possessed of the large incisives and single horn of the Indian species, but its skin has fewer folds, and is entirely covered with small close-set angular tubercles. A third eastern species occurs in Sumatra (*Rh. Sondaicus*, Cuv.). Its skin is more hairy, with scarcely any folds, and there is a small horn behind the ordinary one.[2]

The African species have two horns, no folds on the skin, and want the incisive teeth. The best known is the *Rhinoceros Africanus* of modern writers,—*Rh. bicornis*, Linn. Its name was changed on the discovery of the two-horned Sumatran species, and the title of *African* was bestowed upon it, in the erroneous belief that it was the only species found upon that continent. But the discovery of a distinct species in the interior of southern Africa by Mr Burchell (and which that traveller names *Rh. simus*), affords a proof, among many others which might be adduced, of the impropriety of naming any species from the continent which it inhabits. Few creatures stand so " alone in their glory" as to exist over a vast tract of country without claiming kindred with any other, and it may almost be inferred *a priori* that when one of a genus is discovered, a second or a third will ere long be ascertained. When this happens, such names as *Africanus*, *Americanus*, &c. cease to be discriminating, and consequently lose their value. In the mean time, we have no means of ascertaining the difference in the geographical distribution of the two species of African rhinoceros, or how far their history and description may not have been confounded by travellers. Mr Burchell's species is chiefly distinguished by the truncated form of the lips and nose, and by its general dimensions being much larger. It was first met with amid immense plains near the 26° of south latitude, and was described by the natives as feeding on nothing but grass, while the other is said to browse on shrubs and branches. One or other of the species extends over a great expanse of Africa, where they are much esteemed as food, the tongue especially being regarded as a great delicacy. The hunters of the rhinoceros are called *agageer* in Abyssinia, from agaro to kill, by cutting the hams or tendon of Achilles, with a sword. The eyes of the animal being extremely small, his neck stiff, and his head very ponderous,[3] he seldom turns round so as to see any thing that is not directly before him. To this, according to Bruce, he owes his death, as he never escapes if there is as much plain ground as to enable a horse to get in advance, for his pride and fury then induce him to lay aside all thoughts of escaping but by the victorious overthrow of his enemy. He stands for a moment at bay, then starting forward, he suddenly charges the horse, after the manner of a wild boar,—an animal which he greatly resembles in his general mode of action. The horse, however, easily avoids this heavy though impetuous onset, by turning short aside,—and now is the fatal instant,—for a naked warrior, armed with a ruthless sword, drops from behind the principal hunter, and, unperceived by the huge rhinoceros, who seeks only to wreak his vengeance on his more open enemy, he smites him with a tremendous blow across the tendon of the heel, and thus renders him incapable of further flight. It may be easily conceived that his rage is great, and his resistance vain.

A rhinoceros in confinement will consume towards two hundred pounds of vegetable substances in a day. They are usually fed on moistened beans, hay, carrots, and a certain allowance of grain. In speaking of the supply of vegetable matter essential to the support of so gigantic a living mass, we must likewise bear in mind the vast quantity of water which it consumes. No country, according to Bruce, but such as that of the Shangalla, deluged with six months' rain, full of large and deep basins hewn by nature in the living rock, and shaded from evaporation by dark umbrageous woods, or one watered by extensive and never-failing rivers, can supply the enormous draughts of his capacious maw.[4]

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[1] Griffiths's *Animal Kingdom*, vol. iii. p. 426.

[2] For a description of its habits of life, see Dr Horsfield's *Zoological Researches in Java*.

[3] A head, when disjoined from the vertebræ, is described by Mr Burchell as being of such enormous weight that four men could merely raise it from the ground, and eight were required to place it on a carriage.

[4] We may here note an opinion entertained both by Mr Salt and Baron Cuvier, that the figure of the African rhinoceros given

We shall here briefly notice the Genus HYRAX of Hermann, which seems to contain only a single well authenticated species (*H. capensis* and *syriacus*, figured in Plate XI., fig. 5), described under a variety of names, such as daman, Cape marmot, Cape çavy, &c. It is an animal of the dimensions of a rabbit, with a greyish-coloured fur. It was long classed among the Rodentia, probably on account of the smallness of its size; but, as Cuvier has remarked, with the exception of the horn, which is here wanting, the hyrax may be said to represent the rhinoceros in miniature. It has exactly the same molars, but there are two strong incisives curved downwards in the upper jaw, and, in the young state, a pair of small canines; there are four incisives in the lower jaw. The fore feet have four toes, the hinder three, all furnished with very small rounded hoofs (or rather nails, for in this respect our present genus seems to form an exception to its order), except the inner toe of the hinder extremities, which bears a curved oblique nail. The tail is tubercular. This animal has twenty-one pair of ribs, being exceeded in that number, we believe, by only a single quadruped, the *unau* or two-toed sloth, which has twenty-three. In this character, as in many others, it agrees with the pachydermous tribes in general, all of which have numerous ribs; whereas the majority of the Rodentia have only twelve or thirteen pair of ribs, those of the beaver alone amounting to fifteen. The hyrax is spread over a vast portion of Africa from the Cape of Good Hope to the north of Abyssinia. It dwells in clefts of the rocks, feeding on herbs and roots. Bruce describes it as "found in Ethiopia, in the caverns of the rocks, or under the great stones in the Mountains of the Sun, behind the queen's palace at Koscam. It is also frequent in the deep caverns in the rock in many other parts of Abyssinia." It is there called *ashkoko*, and several dozens are frequently seen sitting together upon great stones at the mouths of caves, enjoying the warmth of the mid-day sun, or the freshness of a fine summer evening. They are gentle and easily tamed, though at first, if roughly handled, they are apt to bite. "In Arabia and Syria he is called Israel's sheep or gannim Israel, for what reason I know not, unless it is chiefly from his frequenting the rocks of Horeb and Sinai, where the children of Israel made their forty years' peregrination; perhaps this name obtains only among the Arabians. I apprehend he is known by that of saphan in the Hebrew, and is the animal commonly called by our translators cuniculus, the rabbit or coney."[1]

GENUS TAPIR, Linn. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{7-7}{7-7}$; $=44$. Muzzle prolonged into a small fleshy trunk, but not prehensile. Anterior feet with four toes, posterior with three. Tail very short.

The most anciently known of this genus is the *Tapir Americanus*, supposed to be the largest quadruped native to the southern division of the New World, where it is very generally distributed from the Isthmus of Panama to the neighbourhood of the Straits of Magellan, being, however, more abundant in Guyana than in Paraguay. Its prevailing colour is deep brown, and there is a small mane on the upper portion of the neck of the male. This species measures nearly six feet in length, with a height of about three feet six inches. It is hunted by means of dogs, on account both of its flesh and hide, the former being held in some esteem by the Indians, whose taste is not distinguished for delicacy. When pursued, it seeks its safety by bursting through close and thorny thickets, where it is with difficulty followed by its thinner skinned enemies. It is also sometimes shot by those who lie in ambush during the night among the water melons, its accustomed food. It is tenacious of life, if we may judge from the account given by Azara, who saw one run for some time after it had received two balls through the heart. It is a solitary animal, of nocturnal habits, easily tamed if taken young. See its cranium on Plate XI., figure 6.

A second American species has been discovered of late years by M. Roulin,[2] and described under the title of *Tapirus pinchaque*. It is nearly equal in size to the preceding, and resembles it in its general form and aspect, but its osteological structure exhibits a considerable difference, and it is said to occur only at a great height among the mountains.

The only other described species is the Malay tapir of Raffles and Horsfield (*Tapir indicus*, Cuv., Plate XI., figure 7). It is a native of Sumatra and the Peninsula of Malacca. It exceeds the American kinds in size, and is further distinguished by a peculiar and contrasted colouring, the head, shoulders, and fore and hind legs being of a blackish-brown, while the intermediate portion of the body is of a dingy white. Though a common animal in the east, its habits in a state of nature are but little known. The specimen described by Sir T. S. Raffles was young and tractable. It roamed about the park at Barrackpore, and was frequently observed to enter a pond and walk along the bottom under water, but without any exercise of the ordinary mode of swimming.[3]

FAMILY III.—SOLIDUNGULA.

We here place the different species of the horse tribe, technically characterized by possessing only one external toe to each foot, covered by a single undivided hoof. But, beneath the skin on each side of the metacarpal and metatarsal bones, are two small protuberances or styles, which represent the lateral toes. The three kinds of teeth exist in the males; the canines are almost always wanting in the females.

GENUS EQUUS, Linn. Incisives $\frac{6}{6}$, canines $\frac{1-1}{1-1}$, molars $\frac{6-6}{6-6}$; $=40$. Upper lip developed and flexible. Eyes lateral. Ears large, pointed, moveable. Limbs long and slender. Tail of medium length, and either furnished throughout its whole extent with long hair, or terminated by a somewhat lengthened tuft. Stomach simple, and of medium size; intestines very long; cœcum enormous.

According to the views of modern naturalists, this important genus consists of six distinct, though nearly allied species, namely, the horse (*Equus caballus*), the dziggithai (*E. hemionus*), the ass (*E. asinus*), the quagga (*E. quagga*), the zebra or mountain zebra (*E. zebra*), and the zebra of the plains (*E. Burchellii*). It has been remarked that the characters which distinguish these animals from each other, though sufficient for the purposes of the naturalist, are not, anatomically considered, of an essential nature. They are rather superficial, consisting chiefly in the comparative size of the ears, the length and texture of the hair, and the distribution of the external colours. As the size varies remarkably in several of the species, the difference of dimension can scarcely be assumed as a specific character. Hence the most accomplished comparative anatomist can with difficulty distinguish a species merely from the inspection of a few isolated bones, although such inspection is amply suffi-

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by Bruce must have been copied, for convenience, from the one-horned species of Buffon, with the addition of a second horn, as the two-horned rhinoceros wants the folds in the skin, which are nevertheless represented by the Abyssinian traveller.

[1] Bruce's *Travels*, Appendix, p. 136, pl. 23. See also the late Dr Scott's Essay in *Wernerian Memoirs*, vol. vi.

[2] *Annales des Sciences Nat.* 1829, t. i. p. 26.

[3] See *Linn. Trans.* vol. xiii. part 2d, and Horsfield's *Zoological Researches*.

cient for the determination of species in the case of almost all other groups of which we possess an osteological knowledge. We shall devote a few sentences to each of the animals above enumerated.

Equus caballus. The Horse. Our cultivated breeds of this invaluable creature are now so numerous, that a volume would scarcely suffice for their record. We shall here confine ourselves to the few facts within our knowledge which illustrate its *natural* history, properly so called,—for one great effort of the zoologist should consist in the distinguishing of facts which depend on instinct, and are therefore natural to an animal, from those which result artificially from education and an altered mode of life,—in ascertaining what really appertains to it as a natural inheritance, as well as what it may have derived through the intervention of man,—and in avoiding to confound "the animal with the slave, the beast of burden with the creature of God."[1] In the present case, however, it must be admitted, that the domestic breeds are improved not more in usefulness than in beauty and grandeur of aspect, whatever poets may fancy to the contrary in a wild horse of the Tartarian deserts. The following are the characters which distinguish this animal in a state of nature. The head is large in proportion to the body; the front, above the eyes, bulging or convex; the forehead straight; the ears long, carried habitually low, and pointing backwards, thus producing a somewhat vicious aspect; the circumference of the mouth and nostrils is garnished with long hairs; the mane is very thick, and prolonged beyond the withers; the back is less vaulted than in the domestic varieties; the legs are proportionally longer and thicker; the hair, sometimes long and waving, is never smooth; its colour, usually dun or brown, sometimes varies to a kind of cream-colour, but is never either black or pied. These are the characters of the *tarpan* or wild horse of the Tartarian deserts; and similar features seem to have been reproduced in the Spanish or Andalusian race, now wild in the pampas of the New World to the south of Buenos Ayres. There the size has decreased, the limbs become thicker, the neck and ears longer, and the varied colouring has, in a great measure, disappeared,—there being usually about ninety chestnut bays in the hundred, while black is so rare that there is scarcely one out of two thousand of that colour. Now, as all emancipated animals exhibit a tendency to recover after a certain lapse of time, and as a consequence of liberty, not merely the manners and instinctive inclinations, but also the form and colour of their primitive types, M. Azara concludes that this chestnut bay is the original hue of the horse. According to Foster there are neither pied nor black horses among the wild troops of central Asia, among which the dun and greyish-brown prevail, and one or other of these is therefore by some regarded as the natural colour. The hair of the South American troops has scarcely increased in length; but this is probably owing to the greater mildness and equality of temperature which prevail in their adopted country, than in the climate of the north of Asia. One remarkable distinction, however, is said to exist between the disposition or temper of the South American and Asiatic wild horses. It is this. At whatever age the former are caught, they may be rendered, in a measure, fit for the service of man almost in a few days, whereas the latter can only be tamed when taken young, and frequently shew themselves in after life to have been but half subdued. Does not this go far to prove that the one is the genuine original,—the other but a rebel race?

The native country of the horse is believed to be those desert regions which environ Lake Aral and the Caspian Sea. Although no doubt exists as to the occurrence of wild, or at least of what may be called independent horses in those countries, as well as in the southern parts of Siberia, in the great Mongolian deserts, and among the *kalkas*, to the northwest of China; yet it ought not to be concealed that some thoughtful inquirers are of opinion that these also, as well as those of America just mentioned, are merely emancipated tribes, descended at some remote period from an enslaved stock, and that the real wild horse, using the expression as we apply it to other animals existing entirely (and *ab initio*) in a state of nature, is extinct. The wild horses, for example, mentioned by Pallas as pasturing in the deserts on each side of the river Don, in the vicinity of the Palus Mæotis, are now believed, if not ascertained, to be the offspring of the Russian horses employed in the siege of Asoph in the year 1697, and which, for want of forage, were at that time intentionally turned adrift. Their descendants have now assumed an aspect of great natural wildness.

In Asia each congregated troop seldom exceeds twenty individuals; but, in America, many thousands are sometimes seen together. In both these distant regions a peculiar variety has sprung up with crisped or frizzled hair; but those of Asia are always white, while the American (frizzled) variety is of every colour except white and pied. When we consider the almost constant relation which may be traced between the length and abundance of hair, and an increased degree of cold, we might have expected to discover this frizzled variety of the New World rather towards the colder country of Patagonia, than in Paraguay, just as the corresponding variety of Asia is found beneath the varying climate of the Baskir nation. According to Azara those magnificent troops of *insurgent* horses (*Alzados* is the Spanish term) which have become wild in the plains of America, to the south of the Rio de la Plata, sometimes amount to 10,000 individuals. Preceded by videttes and detached skirmishers, they advance in a close column so broad and dense that nothing can break through it. If a travelling caravan, or a body of cavalry, is seen approaching, the leaders of the wild horses advance upon a reconnoisance, and then, in accordance with the movements of the chief, the entire body passes at a gallop to the left or right, inviting, at the same time, by a deep prolonged neighing, the domestic horses to desertion. These often join the "rebel host," and are said never voluntarily to submit themselves again to man's dominion. Each of these great squadrons is composed of a re-union of smaller companies, themselves consisting of as many mares as a single horse can keep under a loving subjection. Descended, as we have said, from the ancient breed of Andalusia, these animals are, however, inferior to their noble ancestry in beauty, strength, and swiftness. Their heads are thicker, their limbs coarser and less symmetrical, their necks and ears longer; and, in all these qualities, it has been remarked, they approach again to the supposed primitive model which still exists in a state of freedom, amid the illimitable wilds of the Tartarian deserts. Domestication, therefore, is not, as Buffon has so eloquently maintained, in all cases prejudicial to the nature of an animal; for the *beau ideal* of a horse is undoubtedly to be found, not among the desert tribes, as the French Pliny supposes, but rather in one of the cultivated races of Spanish or Arabian birth.[2]

Equus hemionus, Pallas. The Dziggithai. This species bears a considerable resemblance to a mule in size and figure, but is much more elegant. It is called *Hemionos* (literally half-ass) by Aristotle, and is mentioned by that philosopher as occurring in ancient times. It is of a greyish isabella colour. The coat, during winter, is tufted like that of a camel, but in summer it is scarcely three lines in length, and is distinguished by radiated marks like ears of corn, scattered here and there upon the flanks. The existence of this animal in Syria was known to ancient writers. Ælian describes it as a native of India. The first of the moderns by whom it was recognised appears to have been Messerschmidt; but it is to Pallas that we are indebted for its genuine history. It is confined at the present day to the *steppes* of Central Asia, and is found especially in the desert of Cobi. There is certainly no modern proof of its existence to the west of Lake Aral, and the mountains of Belur. It neither penetrates into forests, nor ascends mountains. Its neighing is more grave and sonorous than that of a horse; and it is described as bearing its head and neck loftily like a stag. It can travel fifty or sixty leagues across the desert without drinking, and its congregated bands do not consist of more than about twenty females and foals, under a single male chief. Sometimes several males are observed together, followed only by four or five females. The rutting season takes place towards the end of August, and the young are produced in spring. There is usually only one brought forth at a time, which attains the adult state in three years. The chase of this animal affords a favourite pastime both to the Monguls and Tanguts; but its prodigious and proverbial swiftness, aided by a piercing sight, and an acute sense of smell, generally baffles the exertions of the most experienced and best mounted huntsmen.

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[1] Buffon.

[2] For a detailed account of the domestic breeds see article HORSE in this Encyclopædia; also Culley's *Observations on Live Stock*, Marshall's *Economy of Yorkshire and the Midland Counties*, the works of Buffon, Bewick, &c.; and the volume entitled *The Horse*, in the farmer's series of the "Library of Useful Knowledge." Our own sketch of the genus *Equus* coincides with, and is indeed chiefly compiled from materials which we had sometime ago occasion to collect from various sources for the formation of an essay "On the Origin and Natural History of the Horse and its allied Species," published in the Edinburgh *Journal of Agriculture*, No. vii.

Equus asinus. The Ass. As in our preceding notice of the nobler horse we dwelt chiefly upon its natural attributes, so in this humble species we may distinguish between the indigenous and subdued kinds. The Onager, or wild ass, called *koulan* by many of the tribes of Asia, differs from the domestic breed in its shorter ears, the greater length and finer form of its limbs, its straighter chest, and more compressed body. In its general aspect, it is said to resemble a young foal. The males alone are characterized by the transverse bar across the shoulders, observable in the domestic ass, and, in the wild species, it is sometimes double. The onager was well known to the ancients, although it appears to have been lost sight of during the dark ages, and to have been but obscurely known for several centuries after the revival of learning. Indeed we possessed no good modern elucidation of its history till the time of Pallas.[1] The Turkish name of this animal, *Dagh aischaki*, or mountain ass, points out its natural locality, elsewhere beautifully indicated,—"Whose house I have made the wilderness, and the barren land his dwelling. The range of the mountains is his pasture, and he seeketh after every green thing."[2] Even the choice which the domestic ass may be often seen to make of the narrow and uneven paths by the wayside, is probably a remnant of this natural instinct. The native country of the wild ass is the same as that of the horse; but, while the latter extends as far north as the 56°, the former does not voluntarily pass beyond the 45°. In its southern migrations, however, it descends to the Persian Gulf, and even towards the southern extremity of Hindostan. It was seen by Odoar Barboza among the mountains of Golconda; and those troops of wild horses mentioned by Turner as frequenting the upland countries of Boutan, where they are called *Gourkhaws*, were, in fact, onagers or wild asses. Eye-witnesses have also assured Pallas of their having frequently observed in the Tartarian deserts, and those of Persia, the route of congregated wild asses, forming a path of 300 toises (above 600 yards) broad. The food of the wild ass, according to Dr Shaw, consists chiefly of saline, or bitter and lactescent plants. It is also fond of salt or brackish water. Its flesh is highly esteemed by several oriental nations, and its skin is known in commerce under the name of chagrin, so called from the Turkish term *sagri*. The engrained aspect which it bears is not, however, natural to it, but is produced by a chemical process described by Pallas. In regard to the domestic ass, its manners and appearance, as it exists in this country, are so familiar as to render description needless. The races of eastern origin are much more beautiful, with glossy skins, carrying their heads loftily, and moving their limbs in a very graceful manner. They accordingly fetch a high price. Some contrariety of opinion exists regarding the progress of their introduction westward, and their great uniformity of aspect, compared with the multiplied varieties of the horse, has induced some to suppose that asses have not been so long nor so generally under the dominion of the human race. In the time of Aristotle they were not found in Thrace, nor even in Gaul; but, on the other hand, we know, from the sacred writings, that they were used as beasts of burden in the remotest ages of the Jewish history, and were, therefore, in all probability reduced to servitude by the eastern nations fully more early than any other animal not essential to the existence of a pastoral people. Buffon is of opinion that the domesticated breed of asses used in Europe came originally from Arabia; that they first passed into Egypt, and thence to Greece, Italy, France, Germany, England, &c. Those used in more northern countries have been introduced at a comparatively recent period. Indeed, even in England, according to Hollinshed, so late as the days of Elizabeth, "our lande did yeelde no asses." If it were so, they must have become extinct, for there is no doubt of their existence in this country during a period long prior to the golden days of "good Queen Bess." They are mentioned in the reign of Athelred, and again in the time of Henry III. They may, however, have been reintroduced to Britain in the time of Elizabeth's successor, upon the renewal of our intercourse with Spain, a country famous for the production of both ass and mule. "The relation of Lucilius," says Sir Thomas Browne, "now become common concerning Crassus, the grandfather of Marcus, the wealthy Roman, that he never laughed but once in all his life, and that was at an ass eating thistles, is something strange. For, if an indifferent and unridiculous object could draw his habitual austereness into a smile, it will be hard to believe he could with perpetuity resist the proper motion thereof."[3]

Equus quagga. The Quagga. This animal measures about four feet in height at the withers. The head and neck are deep blackish-brown, striped with greyish-white lines, transverse upon the cheeks, but longitudinal on the temples and forehead, and forming triangles between the mouth and eyes; the other parts are of a clearer brown, paler beneath, and almost white upon the belly. The mane is blackish, and resembles that of a horse which has been *dressed.* A black line runs along the spine to the tail. The quagga inhabits the karoos or flats of southern Africa, and frequently pastures in company with the zebra, of which it was for a long time regarded as the female. The existence of two so nearly allied species within the same geographical boundaries, and subject to constant association, without any third or intermediate variety having sprung up, may be regarded as a proof that animals of distinct kinds, in a state of freedom, have no sexual intercourse with each other; while the entire similarity, or rather identity of climatic influences, under which these two species co-exist, also demonstrates that neither is derived from the other, but that each has descended from a separate type, and forms a primitive species. The quagga is of a much more docile and pliant disposition than the zebra, and is consequently more easily rendered subservient to domestic uses. A curricle drawn by a pair of these animals has been often seen during the gay season in Hyde Park. The late Lord Morton succeeded in raising mules between the quagga and mare, and, in the course of his experiments, a rather singular circumstance occurred. The mare which had produced the hybrid or mule, gave birth several seasons afterwards to a foal which exhibited decidedly the markings of the quagga coat, although the mother had not, in the mean time, associated except with her natural mate, the horse. Indeed her former friend, the quagga, had been dead for more than a year.

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[1] *Acta Petropolitana*, t. ii.

[2] *Job*, ch. xxix. ver. 6–8.

[3] *Pseudodoxia Epidemica.*

Equus zebra, Linn. *E. montanus*, Burchell. The Zebra, or mountain zebra. This species resembles the mule in shape. Its head is rather large, its ears long, it limbs elegantly small, its body well formed, round, and fleshy. But its most remarkable character consists in the extraordinary regularity of its stripes, or markings of alternate colours, which seem rather an effect of art than the genuine production of nature. The head is striped with delicate bands of black and white, which form a centre in the forehead; the neck is adorned with stripes of the same colour running round it; the body is beautifully variegated with bands running across the back, and ending in points at the belly; and its thighs, legs, ears, and tail, are all beautifully streaked in the same manner.[1] The sexes nearly resemble each other. In the young the dark coloured bands of black or brown are paler. The female carries for twelve months. She has been known to breed in confinement with both the horse and ass. M. F. Cuvier has figured and described a mule produced between a female zebra and a Spanish ass. (See Plate XII., figure 2.) It sucked for a year, and was at first of a peaceable nature, but as it increased in size it lost its resemblance to its mother, and also became very stubborn and mischievous.[2] Its coat, when we last heard of it, was of a deep grey, varied on the withers, legs, and tail, by transverse bands. It never neighed, loved to roll itself on the moist ground, attacked all and sundry both with hoofs and teeth, and was indeed a most unamiable creature. The inhabitants of the Cape have never succeeded in their attempts to reduce the zebra to subjection, although Sparmann records an instance of a rich citizen who, to a certain extent, had managed to subdue them. On attempting, however, on one occasion to yoke them to his chariot, he nearly forfeited his life, for, without warning, they rushed back to their stalls, with every symptom of fury and indignation. Buffon was misinformed when he reported a statement (corrected in one of his supplementary volumes), that zebras were used in Holland. Mr Barrow, however, seems to think, that if judicious means were perseveringly made use of, these gay and fantastic creatures might still be reduced to an available servitude, notwithstanding their naturally wild and vicious disposition; and M. F. Cuvier mentions an instance of a zebra which was so tame as to suffer itself to be handled and mounted without difficulty. This species was known to the ancients under the name of *hippotiger*, a term by which it is well designated, as possessing the form of a horse, with the striped hide of the great feline destroyer.[3]

Equus Burchellii, Gray. *Equus zebra*, Burchell. The Zebra of the plains. Although our knowledge of this beautiful animal is originally due to Mr Burchell, who was the first to perceive that South Africa produced two species (besides the quagga), we seem to owe the more precise settlement of its distinctive characters to Mr W. E. Gray. It appears, in fact, that the traveller above named, after ascertaining that there really were two different kinds of this animal, fell into the error of describing the one previously known as the new species, while he overlooked, or did not sufficiently illustrate, the specific distinctions of the zebra of the plains, regarding it as the kind already well known, although it had, in reality, hitherto escaped the notice of naturalists. "The hoofs of animals," Mr Burchell observes, "destined by nature to inhabit rocky mountains, are, as far as I have observed, of a form very different from those intended for sandy plains; and this form is in itself sufficient to point out the dauw[4] as a separate species. The stripes of the skin will answer that purpose equally well, and shew, at the same time, the great affinity and specific distinction of the ass, which may be characterized by a single stripe across the shoulders. The quagga has many similar marks on the hind and fore part of the body; the zebra is covered with stripes over the head and whole of the body, but the legs are white; and *the wild paarde is striped over every part, even down to the feet*. The zebra and wild paarde may be further distinguished from each other, by the stripes of the former being double; that is, having a paler stripe within it, while the latter, which may be termed *Equus montanus*, is most regularly and beautifully covered with single black and white stripes: added to this, the former is never to be found on the mountains, nor the latter on the plains."[5] It is evident from the preceding descriptions (especially from the line which we have marked in Italics, and which applies exclusively to the old species), and from the comparison instituted by Mr Burchell himself, that although he is entitled to the merit of discovering that there were two distinct kinds, he has applied his new name to the old species, and confounded the new species under an old name. It therefore became imperative that his designations should be changed, because the well known zebra is, in fact, the *mountain horse*, and Mr Burchell's new species is the zebra of the plains. Hence the propriety of the emendations suggested by Mr Gray, who retains the name of zebra, as applying specifically to the animal so called by Linnæus and Buffon; and applies the epithet *Burchellii* to the other species, in deserved honour of the enterprising and intelligent traveller by whom it was discovered.[6] The student will not fail to perceive that the term *montanus*, though retained by Baron Cuvier[7] to distinguish the new species, is inapplicable to an animal which its first describer informs us "is never to be found on the mountains," and which was, in truth, originally applied by inadvertence to another species. We here exhibit a portraiture of the young of Burchell's zebra. (See Plate XII., figure 1.)

ORDER VII.—PECORA; RUMINATING ANIMALS.

This order is deemed by Baron Cuvier to be the most natural and best determined of the class of quadrupeds, as all the species seem constructed on the same model, although the camels present some slight exceptions to the prevailing characters. At all events, it includes species of the highest and most essential value to the human race. The characters of the order are somewhat negative. There are seldom any incisive teeth in the upper jaw, and those of the lower are usually eight in number. Between the incisive teeth and the molars there is an empty space, in which, in certain genera, are implanted the canines. The molars, almost always six on each side of both jaws, have their crowns marked by two double crosses, of which the convexity is turned inwards in the upper, and outwards in the lower teeth. The four limbs are terminated by two toes (hence the title of Bisulca, bestowed by Illiger), each covered by a hoof, and behind these hoofs there are sometimes two small spur-like projections,—the vestiges of lateral toes. The two bones of the metacarpus and metatarsus are united into one, commonly named the *canon* bone; but in certain species the vestiges of lateral bones are observable.

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[1] Bewick's *Quadrupeds*.

[2] *Mam. Lithog.*, 15th livrais.

[3] Dion. Cassius, lib. 75, cap. 14.

[4] The Dauw or wild Paarde of the Hottentots (*Equus Zebra*, Linn.) erroneously regarded by Mr Burchell as the newly discovered species.

[5] *Travels in Africa.*

[6] See a paper entitled "a Revision of the Equidæ," in *Zoological Journal*, vol. i. p. 241.

[7] *Règne Animal*, t. i. p. 253.

The most singular functional character in the natural economy of the tribes of our present order, consists of that *ruminating* faculty from which they derive their most familiar appellation. They possess the power of re-chewing their aliments, by bringing back the food for a second time into the mouth after it has been swallowed; and this power results from the peculiar structure of the stomach, which is in a measure quadruple,—the first three being so disposed in relation to the œsophagus, as to admit of either of them receiving the food. The first and largest is the paunch, which receives the mass of vegetable matter grossly bruised by a first and hasty mastication. It then proceeds into the second called the bonnet, the sides of which have laminæ resembling the combs of the honey-bee. This stomach is small and globular; it soaks the herbage, and compresses it into little pellets, which successively remount to the mouth, to undergo a second mastication. During this process the creature remains quiescent, "bedward ruminating," until all the food previously taken into the paunch has been subjected to it. When thus re-chewed, the aliments descend directly into the third stomach, and from thence into the fourth, the sides of which are plaited or wrinkled. This last is the true organ of digestion, and is analogous to the simple stomach of ordinary animals. As long as the young remain in the condition of sucklings, and are supported only upon milk, the fourth stomach is the largest of the whole, but, as soon as the herbivorous habit commences, and large supplies of bulky food become indispensable, the paunch acquires an enormous development. The intestinal canal is very long in all ruminants, but the larger intestines are but slightly pursed. The cæcum is likewise long and smooth. The fat of these animals hardens more in cooling than that of others, and even becomes brittle. The mammæ are placed between the hinder limbs.

With the exception of the horse and dog, all the most truly valuable species which have yet been subjected to the dominion of man, belong to the ruminating order; for example, sheep, rein-deer, camels, and "the cattle on a thousand hills." These either directly yield us the most important articles of human diet, or afford us the kindly protection of their woolly covering, or provide us with many indispensable articles from their strong tenacious hides; to say nothing of their uses as beasts of burden. They are all provided with antlers or horns, at least in the males,—with the exception of the two genera which contain the camels and musk deer, both of which are hornless. It may be as well to devote a few paragraphs in this place to a brief consideration of the nature of these important parts.

The organs of defence and attack with which the heads of ruminating herbivorous animals are furnished, are called, according to their structure and composition, either *antlers* or *horns*. With the former the stag, roe-buck, rein-deer, elk, are armed; antelopes, goats, sheep, bulls, are provided with the latter. Although both these kinds of defensive organs follow the same mode of formation, in so far as they are prolongations of the frontal bone, and have their materials supplied by bloodvessels, yet there exists between them a considerable distinction in relation to the different distribution of these vessels,—a distinction which occasions the periodical fall of antlers, and the permanence of horns. The bloodvessels of horns are internal, those of antlers external; the former are covered by a corneous substance, and increase from their bases, the latter are, for a time, invested by a prolongation of the skin, and, in growing, appear to sprout from their superior extremities.

Antlers, in their perfect state, according to Cuvier, are true bones, both in their texture and elements. Their external part is hard, compact, and fibrous; their internal spongy but solid. They have no large cells, no medullary cavity, and no sinuses. The bases of antlers adhere to, and form one body with the *os frontis*, in such a manner that at certain ages it is impossible, from their internal texture, to determine the limits between them; but the skin which covers the forehead does not extend further,—an irregularly toothed bony substance called the *burr* surrounding the base, while on the antlers themselves are only to be seen furrows more or less deep,—the vestiges of vessels formerly distributed along their surfaces when in a softer state. These hard and naked organs remain only for one year, the period of their fall varying according to the species; but, when that period approaches, there appears, on sawing them longitudinally, a reddish mark of separation between their bases and the eminence of the frontal bone, by which they are supported. This mark becomes more and more apparent till the osseous particles of that portion at last lose their cohesion. At this period a very slight shock frequently makes the antlers drop off,—two or three days commonly intervening between the fall of the one, and that of the other.

The eminence of the frontal bone, after this period, resembles a bone broken or sawed transversely, and its spongy texture is laid open. The skin of the forehead soon covers it, and, ere long, the new horns make their appearance in the form of tubercles, which continue covered by an extension of the skin, until they acquire their perfect shape and size. During the whole of this time the tubercles are soft and cartilaginous, and under the skin is a true periosteum, in which vessels, sometimes as thick as the little finger, are distributed, and penetrate the mass of cartilage in every direction. This cartilage ossifies gradually as other bones, and finishes by becoming a perfect bone. The burr at the base of the horn now penetrates the indentations through which the vessels pass, and, by its further development, first confines, and finally obstructs their flow.[1] The skin and periosteum being thus deprived of nourishment wither and fall away, and the antlers, now hard, and sharp, and bare, exist for a time in their most "palmy state," ere long, however, to shed their glory either amid the forest's gloom, or on the heathy side of sun-lit mountains. For several years successively, at each renewal, they increase in size and majesty.

It is usually in the months of March and April, when a great increase of vigour and activity is observable in these animals, that the renewal of the antlers takes place, and three weeks, or a month, are said to be sufficient for their total growth. Antlers are the characteristic marks of the male sex, the female of the rein-deer, however, forming an exception to the general rule; for, in that species, the heads of both sexes are armed.

Buffon considered the growth of antlers as a species of animal vegetation, and referred the phenomena of their production, and those attending the budding and expansion of plants, to one and the same law. This view of the matter, so much more fanciful than correct, was no doubt founded upon a limited knowledge of facts. The antlers of the stag certainly begin to shoot in the spring season, when an abundant nourishment (and, according to Buffon, so much the more reparatory in its nature, as being composed of buds containing the most active elements of vegetation!) begins to renovate the strength which the rutting season of the preceding autumn had exhausted; but, that no connection exists between the two classes of phenomena alluded to, is evident from this, that, in species of the same climate, browsing on the same kinds of herbage, the periods of the frontal accession may differ from four to five months. Besides, if the production of antlers depended on the ligneous quality of their nourishment, there would be no assignable reason for the unarmed condition of the females, none of which are provided with antlers, with the exception of that of the rein-deer,—the very species, by the bye, which is the least nourished by ligneous food. Neither can the casting of the antlers be attributed in any way, as some have imagined, to the influence of cold on the circulating system; for those of the roe are reproduced in the middle of winter, while the moulting of the stag is actually retarded by the continuance of cold. On the other hand, certain species of the South American continent lose their antlers about the period of the summer solstice. These, according to the relation of Azara, are not subject to annual loss and renewal, for he observed on the same day, three males, two of which had the antlers old and complete, while those of the other were only half grown. He adds, that not more than one-third of the males renew their antlers in each year.

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[1] See Cuvier's *Comparative Anatomy*, Lect. ii. p. 115.

A more philosophical and better established relation has been demonstrated to exist between the growth and decay of the antlers, and the active or passive state of the generative system. The period of love in this tribe of quadrupeds so well known under the name of *rutting season*, produces a series of remarkable changes in their physical state. The reflux of the animal fluids in a direction contrary to that of the antlers, has so obvious an influence on their fall, that, in climates where the rutting season does not attain to so violent a crisis, the antlers are borne for more than a year, and castration is said to render them permanent, by extinguishing the cause of this counter flow.[1]

We shall now notice the *horns* properly so called, which are formed upon processes of bone, and which grow at their root or base, and chemically considered, bear a great resemblance to the hair, nails, and other external parts of animals. In the third month of conception, while the fœtus of the cow is still inclosed in the membrane, the cartilaginous *os frontis* presents no vestige of the horns. Towards the seventh month, however, it becomes in part ossified, and exhibits on either side a small tubercle, apparently produced by the elevation of the osseous laminæ. These bony tumours soon after appear externally. They raise the skin, which becomes callous at that part, in proportion as the tumour grows. It becomes at last horny as it elongates, and forms a kind of sheath, which covers externally the process of the frontal bone. Within this sheath there are numerous branches of blood-vessels, which serve to nourish the osseous portion. The horns, therefore, are only solid, hard, elastic, and insensible sheaths, which protect the osseous prolongation of the frontal bone. These sheaths are generally of a conical figure, and broadest at the base, the extremity from which they grow. They also present different channels or transverse furrows, which depend on the age of the animal, and denote the number of years it has lived in a very certain manner according to the species.

The texture of the horns appears to be much the same in the goat, sheep, antelope, and ox. They consist of fibres of a substance analogous to hair, which appear agglutinated in a very solid manner. In the first two genera these fibres are short, and covered by superincumbent layers like tiles. In the last two they are longer, more compact, and form elongated horns incased in each other.

The horns of the Rhinoceros already briefly alluded to, seem to differ somewhat from those of ruminating animals. They have no bony part, and are not situated on the *os frontis*, but on the lines of the nose. They are formed, however, of the same substance, and we even observe more distinctly in the horns of this animal the fibres analogous to hair. The base of the horn, indeed, presents externally an infinite number of rigid hairs, which seem to separate from the mass, and render that part rough to the touch. When sawed transversely, and examined with a glass, we perceive a multitude of pores that seem to indicate the intervals resulting from the union of the agglutinated hairs. When divided lengthways, numerous longitudinal and parallel furrows also demonstrate the same structure. This kind of horn is attached to the skin only. Those of the two-horned rhinoceros appear always in some degree movable. When fixed, as in the one-horned species, there is a thick mucus interposed between its base and the bone on which it rests.[2]

In the Giraffe or Camelopard the horns are short and cylindrical, and even in their completed state, are covered with hair, except at the points, which are more bare and callous. Their bases are dilated by very large cells, which are continuous with the frontal sinuses. These horns differ from those of the bull, antelope, &c. in this, that they are not continuations of the frontal bone, but are separated from it and the parietal, by a membranous space; at least such is the structure observable in the young giraffe which was transported to Paris by Delalande. These horns are permanent, and in relation to several of their anatomical and physiological characters, may be regarded as intermediate between the antlers of stags, and the horns properly so called, of the other tribes.

We may observe, in conclusion, that ruminating animals occur in almost all parts of Europe, Asia, Africa, and America. None are native to New Holland.

GENUS CAMELUS, Linn. Incisives $\frac{2}{6}$, canines $\frac{1-1}{1-1}$, false molars $\frac{1-1}{1-1}$, molars $\frac{5-5}{5-5}$; $= 36$. The upper lateral incisors assume the form of canine teeth, and the canines themselves are straight and strong. The head is lengthened, the upper lip cloven, the nostrils consist of two clefts capable of being opened and closed. The eyes are projecting; the ears rather small. The neck and limbs extremely long. The feet are not cloven, but are furnished beneath with a very broad horny sole, and the two toes are each terminated by a small short somewhat curved nail. There are one or more fatty humps along the dorsal region. The mammæ are four in number.

Of this remarkable genus there are two species, or at least two well marked races, usually regarded as distinct. The Bactrian species, or Camel properly so called (*C. Bactrianus*, Linn.), is distinguished by its pair of humps, one above the shoulders, and another near the rump. It is an animal of Asiatic origin, and is said still to occur in the wild state in the desert of Shamo, on the frontiers of the Celestial Empire. It is used as a beast of burden in Turkistan and Thibet, and even as far north as the shores of Lake Baikal. It is consequently capable of being acclimated without much difficulty in any temperate region, and was introduced into Tuscany by the Grand Duke Leopold, where it still breeds in the maremmas of the Pisan district.

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[1] See the article *Cerf* in the *Diction. Classique d'Hist. Nat.*, t. iii. p. 371; consult also the words *Bois* and *Cornes* of the same work.

[2] *Comp. Anat.* Lect. xiv. p. 623.

Though useful as a beast of burden, it is not there employed at all extensively for the general purposes of rural labour, being chiefly occupied in carrying stores of firewood to the city. This animal is more restricted in a southern direction than the single humped species.

The other species of camel usually called the dromedary (*C. dromedarius*, Linn.), has only a single hump upon its back. (See Plate XII., figure 3.) This is now the better known and more abundant of the two, and has spread from Arabia into Syria, Persia, and all over the northern parts of Africa. The name of dromedary (from the Greek δρομεὺς), was originally applied to a swift running variety, but has in the course of time been applied to the species itself. Colonel Hamilton Smith informs us that it is the dromedary that is used in India to precede the nawabs on state occasions, and that a corps of these animals was formerly maintained by the Honourable Company, each being mounted by two men, and armed with musketoons or swivels. At particular seasons they are very savage. If we may judge from the ample covering of woolly hair by which, except towards the termination of the rutting season, both the species are clothed, we should infer that each was originally derived from a comparatively temperate clime. The southern base of the Caucasus has been by some assigned to the dromedary or Arabian species; while the arid plains beneath the northern confines of the Paropamisaden range, with the wilderness of Gasnak and Chorasmia, east of the Caspian Sea, are regarded as the native abodes of the two humped or Bactrian camel. This, it is said, may be inferred from scattered hints in the Zend, the poems of Schah Ferdusi, and from the Arabian Epic, the Romance of Antar.[1] The articles used in manufactures, and known by the names of mohair and camlets, are the produce of the fur of these animals.

Ancient authors do not seem to allude to the camel as an inhabitant of Africa. It is mentioned however in Genesis (chap. xii. v. 16) as among the gifts bestowed by Pharaoh on Abram, and it must therefore have been well known on the banks of the mysterious Nile, at a period prior to that of the most ancient of the Greek or Roman writers. It has indeed been remarked as a singular circumstance, that the Romans who waged such frequent wars in Africa, should not have thought of mentioning these animals, till Procopius noticed camel-riding Moors in arms against Solomon, the Lieutenant of Belisarius.

Genus Auchenia, Illig. Incisives $\frac{2}{6}$, canines $\frac{0-0}{1-1}$, false molars $\frac{1-1}{0-0}$, molars $\frac{5-5}{5-5}$; $=32$. Feet more cloven than in the camels, but supported behind by a small callous sole. No fatty humps upon the back. Mammæ two.

The species of this genus are peculiar to South America, where they may be said to represent the camels of the Old World. Various species have been described by Molina[2] and other writers, but naturalists seem to have failed in establishing the distinctive characters of more than two, the *lama* or *guanaco* (*Camelus llacma*, Linn.), and the *Vigogna* (*Camelus vicugna*, Linn.). Of these the former is as large as a stag. It is covered with long coarse chestnut coloured hair, of varying hue, in the domestic state. It lives in troops upon the cold and lofty ranges of the Andes, and was the only native beast of burden in Peru at the time of the discovery of that country by Europeans. The animal known as the *Alpaca* (see Plate XII., figures 4 and 5) is now regarded as a woolly-haired variety of the lama. The vigogna is of smaller size, and is characterized by a woolly fawn-coloured coat, of a texture so admirably soft and fine as to be highly prized for the fabrication of various stuffs. This species inhabits a vast extent of the Andes in the neighbourhood of the region of perpetual snow. When transported to the lower plains of Chili and Peru it becomes unhealthy, and does not long survive. It is of a more savage nature than the preceding species, and has not yet been effectively reduced to a domestic state. It is alleged never to drink. The vigogna is of a very fearful disposition, and is easily deterred from its accustomed paths of safety by a stretched cord, from which pieces of coloured rags are here and there suspended. In this state of uncertainty and terror it is not only easily shot, but will even allow itself to be approached and seized by the hind legs. Eighty thousand are said to be killed every season in the higher countries of Chili and Peru. As it is for the wool alone that they are massacred, it would probably be more politic rather to sheer than slay them.

Genus Moschus, Linn. (Male) incisives $\frac{0}{8}$, canines $\frac{1-1}{0-0}$, molars $\frac{6-6}{6-6}$; $=34$. (Female) incisives $\frac{0}{8}$, canines $\frac{0-0}{0-0}$, molars $\frac{6-6}{6-6}$; $=32$. The canine teeth in the upper jaw of the males of this genus are long, vertical, compressed, and slightly curved backwards. They protrude considerably from the mouth. (See Plate XII., figure 6.) The feet are hoofed and cloven, like those of the ordinary ruminants. The mammæ are two or four in number.

The musk deer seem confined to the temperate and southern parts of Asia, and the great eastern islands. They are remarkable for their elegant and graceful forms. Although the substance called *musk* has been known throughout Central Asia from time immemorial, it does not appear that the species which produced it was described by the ancients, or in any way identified till the days of Abuzeid Serassi, an Arabian author, who mentions it as a deer without horns. A knowledge of it seems to have been first introduced into Western Europe by Serapion, a writer of the eighth century. The musk deer, properly so called (*Moschus moschiferus*, Linn.) is nearly as large as a roebuck, and occurs over a vast extent of Central Asia, from Thibet to the vicinity of Lake Baikal. It is also frequent in many parts of India, and the mountainous provinces of the Chinese empire. The prized perfume is obtained from a small bag placed in the lower region of the abdomen of the males. There are various modes of capturing the musk deer or *che-kiang*, as it is called in the East. It is frequently shot. The sportsman, however, must climb among the mountain fastnesses like a chamois hunter, and ascend towards the most inaccessible places. It is also taken by nets and gins, or by encumbering the sides of some deep and lonesome defile by a kind of palisade of thick and prickly bushes. Several other species of this genus have been described by naturalists, such as the *napu* or Java musk (*M. javanicus*, Raffles,[3] see Plate XII., figure 7), and the beautiful Chevotrain (*M. pygmæus*), one of the smallest of the ruminating order. The body of the latter does not measure more than eight inches long. The *minima* is a Ceylonese species first described by Knox.[4]

In all the ensuing genera of the ruminating tribes, the head (at least of the males) is furnished with antlers or horns.

Genus Cervus, Linn. Teeth of the same amount as in the preceding genus; the canines of the males, however, being shorter. Branched antlers, solid and deciduous, and of greater or less extent, according to age, and the constitution of each particular kind. Mammæ four.

This genus contains those magnificent and diversified species commonly called Deer. These animals are, with few exceptions, characterized by extremely graceful forms, by light but strong proportions, and by the energy and activity of their general movements. As constituting the noblest objects of the chase, as well as affording the choicest subjects for the larder, they have long been regarded with great interest by the human race. The genus is distributed over all the greater divisions of the earth, with the exception of New Holland, and its numerous species have been formed in modern times into many minor groups, an exposition of the detailed complexities of which would be incompatible with the compendious nature of the present treatise.[1]

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[1] Griffith's *Animal Kingdom*, vol. iv. p. 46. See also M. Desmoulins' *Memoire sur la Patrie du Chameau*, &c. in *Mem. du Mus.* t. ix.

[2] *Storia Naturale del Chili.* For the various species, real or supposed, see also the *Synopsis of Mammalia* (in Griffith's *Animal Kingdom*, vol. v.), and the article *Chameau* in *Diction. Classique d'Hist. Nat.* t. iii. p. 447.

[3] *Linn. Trans.* vol. xiii.

[4] In his *Historical Relation of Ceylon.*

Two species (the rein-deer and the elk) seem common to the northern parts of Europe and America; five or six are peculiar to North America; about an equal number occur in the New World, south of the equator; and a much greater variety inhabit India, China, and the great islands of the south-east of Asia. The generality of deer vary in colour according to age and season, and are subject to those constitutional changes which physiologists distinguish by the names of *albinism* and *melanism*,—the former applied to the white, the latter to the black varieties of colour. M. Desmoulins has remarked the singular circumstance, that the white varieties occur more frequently in equatorial regions than in the colder countries of the north; a proof, perhaps, that the intensity of light and heat are but secondary causes in the production of animal colours. We shall proceed to a brief notice of a few of the more remarkable species.

The elk (*Cervus alces*, Linn., see Plate XII., figure 9), called moose-deer in America, is the most gigantic of the genus, and is easily recognised by the great height of its limbs, the shortness of its neck, its lengthened head, projecting muzzle, and short upright mane. Its general aspect seems rather disproportioned and ungraceful. When full grown it measures about six feet in height. The fur is long, thick, extremely coarse, of a hoary brown colour, but varying considerably in hue with age and season. The antlers are of great breadth and solidity, plain along their inner or backward margins, but armed externally with numerous sharp pointed snags or shoots, which sometimes amount to nearly thirty in number.[2] A single antler has been known to weigh about sixty pounds. Although the muzzle of the elk is long and flexible, yet, owing to the shortness of its neck, it gathers its food with difficulty, or at least in a constrained and awkward posture, from the surface of the ground. Hence its propensity to browse upon the tender twigs and leaves of various shrubs and trees; a mode of feeding frequently exhibited by the individual in the gardens of the Paris Museum. In the northern parts of America elks live in small troops, and are fond of swampy places. The old ones lose their horns in January and February, the young in April and May. They were formerly found as far south as the Ohio, but at present they occur only in the more northern portions of the United States, and beyond the great lakes. Although they form small herds in Canada, they are very solitary in all the more northern districts, where two are seldom seen together except during the rutting season, or when the female is accompanied by her fawns. Sir John Franklin met with several during one of his expeditions feeding on willows at the mouth of the Mackenzie River, in lat. 69°.

This great species is one of the shyest and most wary of the deer tribe. It is an inoffensive animal, unless when irritated by a wound, or under the influence of the rutting season. When provoked, by whatever cause, its prodigious strength renders it almost irresistible, and it will kill the largest dog or the fiercest wolf in a moment by a single blow of its fore foot. It is much sought after by the American Indians on account of its flesh, which, though coarse grained, and tougher than most other kinds of venison, has a palatable flavour, somewhat resembling that of beef. The nose and tongue are particularly esteemed. The hide is of value in the making of canoes, and of several articles of dress. A fine male elk will weigh twelve hundred pounds. This animal occurs (as far as yet known, specifically the same) in several of the northern countries of Europe, especially Scandinavia, between 53° and 63°. It is also found in Asia, where it is said to advance (in Tartary) as far south as the 45°. The *ancient* history of the elk consists of but little else than a series of absurd fables. Neither the Greek nor Roman writers knew any thing of its actual existence in any of those territories which they overran, although the former received exaggerated accounts from the Scythians, the latter from the Germans, of its extraordinary aspect and character. It was said to have no joints to its legs, to have antlers growing from its eye-lids, to be incapable of browsing except when walking backwards, while its origin was traced to a productive union between the stag and camel.

Another noted species, likewise extensively distributed over the northern parts of both the Old and New World, is the rein-deer (*Cervus tarandus*, Linn., see Plate XII., figure 8). It has long been domesticated in the Scandinavian peninsula, and is an animal of indispensable importance to the forlorn families of the Lapland race. We are less acquainted with the domestic manners of the American variety, which indeed has never been rendered subservient to man. There appears to be two distinct or well marked races of the rein-deer in the fur countries of the New World. One of these is confined to the woody and more southern districts, while the other retires to the woods only during the winter season, and passes the bright but fleeting summer either in what is called the barren grounds, or along the shores of the Arctic Ocean. Those of the barren grounds are small of stature, and so light that a hunter can carry a full grown doe across his shoulders. Sir J. Richardson is of opinion that when in prime condition the flavour of its flesh is superior to that of the finest English mutton. He was probably hungrier in America than he has ever been at home. The other variety is much larger, and is usually called the woodland caribou. It is, however, much inferior as an article of diet. One of the most remarkable peculiarities of this animal is that it travels *southwards* in the *spring*, crossing the Nelson and the Severn Rivers in vast herds during the month of May, with a view to spend the summer on the low marshy shores of James's Bay, and returning inland, in a *northerly* direction, in September. The provision called *pemmican*, so essential to the subsistence of our Arctic travellers, is formed by pouring one-third part of melted fat over the flesh of the rein-deer, after it is dried and pounded. We may add, that of all the cervine animals of America, this species is the most easily approached, and immense numbers are annually slain by the Indian hunters. Indeed, the very existence of several of the native northern tribes may be said to be linked to that of the animal in question.

The European rein-deer, in its domestic state, is of infinite advantage to the Laplanders, serving at once as a substitute for the horse, the cow, the sheep, and the goat. Several attempts have been made to introduce it into Britain, but without any permanent success. It would probably succeed better among the rocky hills of the Hebrides than in the more luxuriant pastures of the south. Those introduced by Sir H. G. Liddell, in 1786, although some of them produced young, and gave promise of a healthy life, died of a complaint similar to the *rot* in sheep. This was attributed to the richness of the grass on which they fed. A buck rein-deer lived nearly three years not far from Hackney. He was kept in a close of about an acre, the grass of which was rich, and he fed constantly on it throughout the year, though much fonder of a small supply of *lichen* which was sent over from Norway, and which, extremely abundant on almost all the rocky grounds of Scandinavia, constitutes his natural food. He would fondly follow any one who held even a shred of it in his hand. When put into a garden where there existed a considerable variety both of flowering shrubs and forest-trees, the individual in question was observed to browse upon them all except the elder. He drank a great quantity of water. This animal cast his antlers in winter for two successive seasons, and renewed them in the spring. During one of these years they continued in the state of stumps till the 30th of January, when they began to shoot; on the 24th of February they were five or six inches high, and covered by a deep pile of velvet hair. It may possibly be unsafe to reason generally from one individual in a state of confinement; but this account does certainly not agree with that of Leems, who, in his ninth chapter, states that the rein-deer loses his horns in spring. Both Hoffberg and Buffon indeed assert the contrary, yet, as Leems lived ten years in Lapland, his opportunities of personal observation must have exceeded those of all other naturalists; and we may add, that his account is more consistent with the fact mentioned by so many travellers, that the rein-deer makes use of its brow antlers to remove the snow from the ground in winter; a circumstance also recorded by several of those very compilers who at the same time, with characteristic inconsistency, deny the animal its antlers during that inclement season. Leems, however, expressly says that the rein-deer procures the lichen by means of its feet. He adds, that it also kills a great quantity of mice, of which it devours the heads with great avidity,—a most singular propensity in a ruminating animal.[1]

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[1] For an ample account and classification of the antlered ruminants, see Griffith's *Animal Kingdom*, vols. iv. and v.

[2] The antlers as represented by the figure last referred to are immature.

Contrary to the usual rule, the female rein-deer is provided with horns, as well as the male,—a fact mentioned by Julius Cæsar, who records the species as an inhabitant of the Hercynian forest, that "boundless contiguity of shade" which is supposed to have extended as far as the Uralian Mountains. In truth, a vast quantity of rein-deer horns are still found in the sandy banks of the Olenia, a stream which flows into the Wolga, about forty wersts below Sarepta. Pallas observes that the steppes to the east of the Wolga were of old clothed with forests; and herds of wild rein-deer are still found among the pine woods which stretch from the banks of the Oufa, under the fifty-fifth degree, to those of the Kama. They proceed even farther south, along the woody summits of that prolongation of the Uralian Mountains which stretches between the Don and the Wolga, as far as the forty-sixth degree. The species thus advances almost to the base of the Caucasian Mountains, along the banks of the Kouma, where scarcely a winter passes without a few being shot by the Kalmucks, under a latitude two degrees to the south of Astracan. This remarkable inequality of the polar distances in the geographical positions of this species, according to the difference of meridian, is of course dependent on the laws which regulate the distribution of heat over the earth's surface, as explained by Humboldt.[2] It is well known that physical climates do not lie, as it were, in bands parallel to the equator, but that the isothermal lines recede from the pole in the interior of continents, and advance towards it as we approach the shores. It follows that the farther any northern animal is naturally removed from the ameliorating climatic influence of the ocean, the more extended may be its range in a southerly direction.[3]

We can here scarcely do more than name the wapiti or Canadian stag (*Cervus canadensis*, Gmelin, *C. strongyloceros*, Schreber), described under the name of red-deer by Mr Warden. It is not, however, specifically the same as the animal so called in Britain, being about a fourth larger, and farther distinguished by the extreme shortness of its tail. According to Hearne, it is the most stupid of all the deer tribe.

The fallow-deer (*Cervus dama*, Linn.) of our inclosed parks, is now scarcely known except in the domestic state. Some incline to regard it as originally an African species, in consequence of an individual having been shot some years ago, apparently wild, in a wood to the south of Tunis. It is easily distinguished from our native red-deer, by its smaller size, its longer tail, and the palmation or breadth of its antlers, a character which induced its ancient name of *platyceros*. It is very common in the southern countries of Europe, but rare in Sweden and other northern regions. According to Linnæus it does not occur in the latter country except in the parks of the king and the nobility, although it sometimes escapes by chance into the forests. It is said to be now frequent in the forests of Lithuania, from whence, according to Raczinsky, the parks of the Polish nobles were in use to be supplied. But it is not included by Pallas in his Catalogue of Russian Animals.[1] In Livonia it requires to be sheltered during the winter season. It abounds in Sardinia, and in several of the Greek and other islands of the Mediterranean. The evidence of its existence in the higher countries of Asia, and onwards through the Chinese dominions, is too obscure to be depended on as truly applicable to this particular species. If not indigenous to France and Spain, the period of its introduction to these countries must have been remote. Two permanent varieties seem to exist in Britain, viz. a spotted kind supposed by Pennant to have been transmitted from Bengal, and a kind of a dark brown colour alleged to have been introduced by James I. from Norway into Scotland, and thence transported to the chaces of Enfield and Epping. It is possible that the existence of the spotted species called Axis in India, may have led to the first idea,—presumed to be erroneous from the fact of the *spotted buck* being noticed in Gwillims' *Heraldry* (4th edition, 1660), where it is quoted as being borne on ancient coats of arms, at least anterior to British intercourse with the east; and it may perhaps militate against the introduction from Norway of our darker brown variety, that Pontoppidan, in his natural history of that country, makes no mention of fallow-deer of any hue whatever.

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[1] See Leems's *Account of Finmark and Lapland*, and Barrington's *Miscellanies*.

[2] In the *Memoires d'Arcueil*, t. iii.

[3] Although we have already assigned a greater space to our notice of the rein-deer than our limits can well afford, we yet cannot refrain from here alluding to a curious point in what may be called the literary history of the species, which, till it was cleared up by the sagacity of Baron Cuvier, had greatly perplexed the naturalist. It was an opinion very generally received, that the reindeer had existed in France, at least in the Pyrenees, as late as the fourteenth century; which opinion brought along with it several others regarding the changes of temperature which bad taken place in Europe, and the origin of many fossil bones. It was first broached by Buffon, however contrary it may seem to his own system, which maintains the gradually increasing coldness of our globe. "Quinze siecle," says Buffon (xii. 83), "après Jules-Cesar, *Gaston Phœbus* semble parler du renne sous le nom de rangier, comme d'un animal qui auroit existé de son temps dans nos forets de France," &c. This Gaston Phæbus was Gaston III. Count of Foix and Lord of Bearn, born in the year 1331, and author of a book entitled, *Le Miroir de Phebus des deduits de la Chasse*, in which the rein-deer is described with tolerable accuracy. As Gaston de Foix's territories lay at the foot of the Pyrenees, it was hence inferred that he had there seen the animal in question; and on this erroneous supposition the Count de Mellin, Schreber, and others, have proceeded in their history of the species. It first occurred to Cuvier to compare the different early editions of the work, to see if any thing could be thereby elicited; but the most beautiful, that of Antoine Verard, led him farther from the truth than ever. He there found the following passage: *J'en ai veu en Morienne et Pueudeve oultre mer, mais en Romain pays en ay je plus veu.* Of course, the existence of the rein-deer in Mauritania would have been still more extraordinary than at Béarn. He next had recourse to a search among the manuscripts of the royal library, where he fortunately found the original of the work in question, as presented by Gaston himself to Philip the Bold, Duke of Burgundy; and on referring to the particular passage, he found all obscurity at once removed. It is there clearly written: "J'en ai veu en *Nourvegue* et *Xuedene* et en ha oultre mer, mes en Romain pays en ay je peu vus." Now, Norway and Sweden were the very countries of which the rein-deer had been described as an inhabitant by Albertus Magnus, about a century before the time of Gaston, and where, we need scarcely say, they still exist in great abundance. The interest which this inquiry excited induced an examination of Froissart and other ancient chroniclers, from whom it appeared that Gaston de Foix, as was usual for the cavaliers of the fourteenth century, had at an early age joined a crusade in favour of the distressed Teutonic knights against the Paynims of Lithuania; that he was passionately fond of hunting, usually entertained 1600 dogs, and at last died of fatigue in consequence of his exertions in pursuing a bear. Hence Cuvier naturally inferred, that after his journey into Prussia, he had been induced, by curiosity or the love of sport, to cross the Baltic Sea and traverse Scandinavia, where the numerous troops of reindeer could not have failed to attract the notice of "a mighty hunter." There is therefore no reason whatever for supposing that this species ever inhabited the mountains of the Pyrenees, or any of the southern countries of Europe. See Cuvier's *Note sur la pretendue existence du Renne en France dans le moyen age*, read to the Institute, and published in the *Ossemens Fossiles*, t. vi. p. 119 (of the 4th edition, 1835).

The stag or red-deer (*Cervus elephas*, Linn.) is the most stately and magnificent of all the wild animals still indigenous to Britain. Vast herds continue to range the mountains in various parts of Scotland, and the species is not unfrequent in the larger of our western islands, such as Mull and Jura. In the southern quarters of the island, the breed is almost extinct in the wild state. It is a shy and wary creature, finely endowed with the sense of smell, not easily approached by the hunter, even from the leeward, and extremely dangerous to encounter closely, from its great strength and occasional courage. Many instances are recorded of its having killed both men and dogs, and one is known of its having beat off a tiger which was let loose upon it in an inclosed area, at the instance of William duke of Cumberland. Its flesh, though lauded by Dr Johnston, and by no means to be despised by a hungry sportsman in the wilds of Scotland, is in our opinion poorer and less highly flavoured than that of the fallow-deer. Of course it is not so easily *selected*, or in any other way obtained in prime condition, and the necessity of eating it occasionally when lean and tough may possibly have proved injurious to its culinary character. Both sexes of the red-deer have obtuse canine teeth in the upper jaw. The age of a stag may be pretty easily determined by the branches of the antlers till its seventh or eighth year; but after that period the increase of those parts is not subjected to any fixed rule. The oldest have seldom more than ten or twelve branches, though an instance has occurred of there being thirty-three on each antler.[2] According to Cuvier, the older the individual, the deeper are the furrows of the antlers.

The only other British species of the deer tribe is the roe (*Cervus capreolus*, Linn.). This beautiful animal, so well known to the Scottish sportsmen, is believed to be now extinct in the southern portions of the kingdom.[3] It differs from the generality of the deer kind in not being gregarious, seldom more than a single family being found together. The roe rarely measures above two feet in height, with a length of about three feet four inches. The antlers are about eight inches long, and are usually divided at the top into three branches. The colours of the fur vary with the season, being bright tawny-brown in summer, in winter more grizzled and obscure. The hair is long, and when inspected minutely, is found to be generally ash-colour at the base, black towards the point, with the point itself yellow. The rump and lower parts are white. This species is certainly confined to the Ancient World, although by a misapplication of the name, it has been believed by many to occur in America. It is common in Scotland, and is found pretty generally, though not in great abundance, in what may be called the Central Zone of Europe. It is rare in France, and is known to have been almost entirely extirpated from Burgundy during the cold winter of 1709. The places where it loves to dwell are woody districts, varied by open glades, and broken in upon by land capable of cultivation. It does not ascend those sterile mountain tracts where the red-deer is so often found. According to Captain Williamson, the roe occurs on the borders of Bengal, particularly among the crags and ravines of the western frontier.

We shall now notice a very few of the more southern foreign species. It has been observed in general, that few of these change their colours with the season. Several magnificent examples of this tribe of animals are to be found on the southern sides of the Nepaul Mountains. Of these we have here exhibited the Nepaul stag (*Cervus Wallichii*, Plate XIII., figure 1), a species which in many respects exhibits a resemblance to the red-deer of our native heath-clad mountains. We scarcely know, as yet, of any other individual than that brought down by Dr Wallich to Calcutta. A drawing was made of it in the living state, by a native artist, and transmitted by M. Duvaucel to Paris, where it was published by M. F. Cuvier. The horns are shorter and less magnificently branched than in the Scottish species, but they have been supposed to have been dwarfed, in the individual in question, by the decrepitude of age. Each has a pair of small brow antlers at the base, and somewhat more than half way up the beam, a small snag turns forwards.

The *Rusa* group of stags is entirely Asiatic, and is distinguished by rounded horns, with a brow antler, but without any median or besantler, and the beam terminates in a single perch, with a snag more or less elongated, placed midway or higher on its anterior or posterior edge. The great Rusa (*Cervus hippelaphus*, Cuv.) almost equals the height of a horse. It has trifurcated horns, and very coarse fulvous brown hair, which changes to a greyer hue in winter. The tail is rather long, and there is no disk on the buttock. This species seems to correspond to the great axis of Pennant. It occurs in several of the Asiatic islands, and in Continental India is found chiefly in the Jungleterry district of Bengal. The exact nature of the animal described by Aristotle under the name of ἵππελαφος, has been a subject of some controversy. The term was formerly applied to a species which occurs in the forests of Germany; but, according to the researches of M. Duvaucel, it is undoubtedly the black deer or black rusa of Bengal (*Cervus Aristotelis*, Cuv.). Its horns are forked at the extremity, and bear only a single branch at the base, similar, as Aristotle expressed it, to those of a roe. It inhabits the Prauss jungles, and is known by the name of *Saumer*.

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[1] See the *Ossemens Fossiles*, t. iv. p. 29.

[2] We allude to the animal killed by the king of Prussia in 1669, and presented to Augustus I. Elector of Saxony and King of Poland. According to Bechstein, the head is still preserved at Moritzburg.

[3] "The particular periods, therefore, when the wolf and wild boar became extinct in this country cannot with precision be accurately ascertained; but the history and fall of the roebuck are better known. It continued to be an inhabitant of England till within the last century, and was not unfrequently met with on the wastes, a small distance from Hexham, in Northumberland. As the breed, however, became gradually more scarce, it was sought for with greater eagerness; so that after enduring the united attacks of the dog and gun for a few seasons, it at length dwindled away into one solitary animal, which about forty years since is said to have been destroyed by —— Whitfield, Esq. of Whitfield, in Northumberland."—*The Sportsman's Cabinet*, vol. ii. p. 172.

The male is nearly as large as an elk (which name, indeed, is erroneously applied to it by many Anglo-Indians), and is represented by British sportsmen in the east as extremely vicious as well as strong. Its prevailing colour in summer is dark brown, in winter nearly black. The abdomen, and a ring around the mouth and nostrils, are whitish, the insides of the legs fawn colour. Captain Williamson describes it as attaining to the dimensions of a Lincolnshire cart-horse (fifteen or sixteen hands high), of a shining black colour, with tan points; the female mouse-coloured.

The spotted axis of India (*Cervus axis*) resembles the fallow-deer, but is easily distinguished by the roundness of its horns, and the want of a terminal palm. The female, however, greatly resembles the doe of our domesticated species. This kind is most frequent in Bengal, and on the banks of the Ganges, although it occurs throughout India, as well in the Eastern Archipelago. It has been frequently imported into Europe, and breeds freely both in France and England. The sense of smell is extremely refined in the spotted axis,—so much so, that although extremely fond of bread, it refuses to eat a piece that has been previously blown upon,—so at least states M. F. Cuvier, regarding the individual observed in the Paris garden. Its disposition in the captive state is otherwise remarkably mild and accommodating.

Passing over the *Muntjaks*, which are numerous in India and the Eastern Islands, we come to a very peculiar animal, the Giraffe, constituting the

GENUS CAMELOPARDALIS, Linn. Incisives $\frac{0}{8}$, canines wanting molars $\frac{6-6}{6-6}$; $= 32$. Head lengthened, with a bony tubercle on the middle of the face, and two bony projections on the forehead, covered by the fur, and terminated by a tuft of longer hairs. The fore-quarters are very high in comparison with the hinder, and the dorsal line is consequently oblique. The neck is of extraordinary length, and the limbs are slender, and terminated by cloven hoofs, resembling those of the ordinary ruminants. There is a callosity on the sternum. The mammæ are four in number.

The giraffe or camelopard, the tallest, and in many other respects one of the most remarkable of quadrupeds, is entirely peculiar to the African continent. Its appearance is too familiar in books of natural history to require a detailed description. (See Plate XIII., figure 4.) We shall merely mention that it measures from fifteen to twenty feet in height, including the lengthened neck. It is a timid and gentle animal, browsing habitually on the foliage of trees, especially those of the Acacia and Mimosa tribes. Its gait or mode of progression is thus described by Mr Lichtenstein: "We had hardly travelled an hour when the Hottentots called our attention to some object on a hill not far off on the left hand, which seemed to move. The head of something appeared almost immediately after, feeding on the other side of the hill, and it was concluded that it must be that of a very large animal. This was confirmed, when, after going scarcely a hundred steps further, two tall swan-necked giraffes stood almost directly before us. Our transports were indescribable, particularly as the creatures themselves did not perceive us, and therefore gave us full time to examine them, and to prepare for an earnest and serious chase. The one was smaller, and of a paler colour than the other, which Vischer immediately pronounced to be a colt, the child of the larger. Our horses were saddled, and our guns loaded in an instant, when the chace commenced. Since all the wild animals of Africa run against the wind, so that we were pretty well assured which way the course of these objects of our ardent wishes would be directed, Vischer, as the most experienced hunter, separated himself from us, and by a circuit took the animals in front, that he might stop their way, while I was to attack them in the rear. I had almost got within shot of them when they perceived me, and began to fly in the direction we expected. But their flight was beyond all idea so extraordinary, that between laughter, astonishment, and delight, I almost forgot my designs upon the harmless creatures' lives. From the extravagant disproportion between the height of the fore to that of the hinder parts, and of the height to the length of the animal, great obstacles are presented to its moving with any degree of swiftness. When Le Vaillant asserts that he has seen the giraffe trot, he spares me any farther trouble in proving that this animal never presented itself alive before him.[1] How in the world should an animal so disproportioned in height before and behind trot? The giraffe can only gallop, as I can affirm from my own experience, having seen between forty and fifty at different times, both in their slow and hasty movements, for they only stop when they are feeding quietly. But this gallop is so heavy and unwieldy, and seems performed with so much labour, that in a distance of more than a hundred paces, comparing the ground cleared with the size of the animal and of the surrounding objects, it might almost be said that a man goes faster on foot. The heaviness of the movement is only compensated by the length of the steps, each one of which clears, on a moderate computation, from twelve to sixteen feet."[2] A tolerably good horse overtakes the giraffe without difficulty, especially over rising ground.

That there is more than a single species of camelopard, is a point rather surmised than demonstrated by our modern naturalists. Some are inclined to infer, chiefly we presume from the difference in their geographical position, that the southern kind, so frequently alluded to in the travels of Le Vaillant, Burchell, and others, are probably distinct from those seen during the expedition of Denham and Clapperton, and more recently described by Ruppel. Camelopards were well known to the ancients, and were shewn in the Circæan Games by Cæsar the Dictator. The Emperor Gordian afterwards exhibited ten at a single shew; and tolerably accurate figures of these extraordinary creatures, both in a browzing and grazing position, have been handed down by the Prænestine pavement. During the darker ages, and indeed for some centuries after the revival of learning, they seem to have been unknown to Europeans; but about the middle of the sixteenth century, the Emperor of Germany, Fredericus Ænobarbus, received one from the Sultan of Babylon. Lorenzo de Medicis was also presented with a live specimen by the Bey of Tunis. Nearer our own times, the camelopard is described in a letter from Captain Carteret to Dr Maty, as having been killed in a journey from the Cape, in 1761;[3] yet the first statements of the unfortunate but accurate Vaillant were almost discredited till he transmitted the giant spoils to Europe. Very recently several live specimens have been transmitted from Kordofan to the gardens of the Zoological Society of London, and they have since bred in England.

GENUS ANTILOPE, Cuv. Incisives $\frac{0}{8}$, canines wanting, molars $\frac{6-6}{6-6}$; $= 32$. Bony nucleus of the horns solid like those of deer. Form light, and well adapted for great swiftness.

This numerous and varied genus has been recently divided into many minor groups, chiefly in accordance with the form of the horns. Of the far greater number Africa is the native country. These creatures are by many regarded as the most lively, graceful, and beautifully proportioned of the brute creation. They have indeed attracted the admiration of mankind from the earliest ages, and the beauty of their dark lustrous liquid eyes has afforded a constant theme for the imagination of the eastern poets. Their names are of frequent occurrence in the most ancient mythologies, and their figures are represented among the oldest of the astronomical symbols. Naturalists are more or less acquainted with about sixty species,—a few of which we shall here briefly notice.[1]

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[1] We have elsewhere observed, that it would have been more becoming and equally logical in Mr Lichtenstein to have inferred rather that Le Vaillant misapplied the term which he made use of to designate the movements of the camelopard, than that he imagined himself to have seen an animal alive which had never presented itself to him in that condition.

[2] *Voyage au Cap de Bonne Espérance.*

[3] See *Phil. Trans.* 1770.

The antelope, commonly so called (*Antilope cervicapra*, Pallas, Plate XIII., figure 5), is an eastern species, distinguished by the triple curve of its annulated horns. These parts are extremely sharp pointed, and in India offensive weapons of great power are made, by joining two pair together at their bases. " Thus are they doubly armed." The female is hornless.

The gazelle, or Barbary antelope (*A. dorcas*, Linn.), is somewhat less than our own roebuck. The horns are black, round, lyrate, with numerous rings, and measure about a foot in length. It is widely spread over northern Africa, and occurs in Persia and the southern parts of Syria. It is a gregarious species of great beauty, much esteemed by lions and other beasts of prey, and although in many respects well known to naturalists, it is yet difficult to draw a precise distinctive line between it and several other closely allied kinds, such as the *kevel*, the *korin*, and the *tzeiran* of the Persians. The gazelle is accurately described by Ælian under the title of *dorcas*, a name bestowed by other ancient writers on the roe. This is the species which, by reason of its exquisite grace and beauty, affords so continued a subject of comparison, and is so often used as a poetical image by eastern writers.

> " Her eyes dark charms 'twere vain to tell,
> But look on those of the gazelle,
> They will assist thy fancy well."

We have figured the head (Plate XIII., figure 3), of a closely allied species called the corinne (*Ant. corinna*, Gmelin). It differs from the gazelle chiefly in having more slender horns. " Ce n'est peut être," says Cuvier, " qu'une variété de sexe."

The Chinese antelope, or Dzerin, of the Mongolian Tartars (*A. gutturosa*, Pallas), is of a heavier form than the preceding, with short thick horns, reclining backwards, divergent, wavy, and the points turned inwards. One of its chief characteristics is a large moveable protuberance on the throat, occasioned by a dilatation of the larynx,—particularly observable in the old males. This is the species known in China by the name of Hoang-yang, or the yellow goat. It occurs also in the deserts between the celestial empire and Thibet, and extends eastward into Siberia, and over that vast expansion so vaguely known under the name of the Desert of Cobi. It is said to avoid woody places, and to prefer open plains and barren mountains. It is an animal of great swiftness, and long endurance of fatigue.

The oryx or algazel (*A. leucoryx*, Lich.? *A. gazella*, Linn. Plate XIII., figure 2) measures above three feet and a half in height at the shoulder. The body is rather bulky, the limbs slender, the horns of the male horizontal, bent backwards, obliquely annulated, with smooth tips, and nearly three feet long. It inhabits sandy districts in Persia and Arabia, and has been shot on the western side of the Indus, in the deserts of the Mekran. We may here notice a remarkable species called the *chiru* (*A. kemas*? Smith), an inhabitant of those inaccessible and piny regions of Chandang which verge on the eternal snows of the Himmaleh Mountains. It sometimes occurs with only a single horn, and in that accidental or imperfect condition is supposed to have given rise to the belief in *monocerotes* or unicorns,—animals which all who are conversant with the structure of skulls, and the position of the frontal sutures, are well aware cannot exist in any accordance with the general laws of organic form. This species is remarkable also for an abundant coating of wool,—a provision bountifully connected with its position as a mountain dweller in a cold and icy clime. The Caffrarian oryx (*A. oryx*) is not more remarkable for beauty of form than for its great strength and vigour. It dwells in elevated forests, and among rocky regions in Southern Africa, and is exceedingly fierce during the rutting season, especially when wounded. A friend of Colonel Smith's having fired at an individual of this species, it immediately turned upon his dogs, and transfixed one of them upon the spot. They are said to afford the best venison of any of the antelopes of Southern Africa.

The blue antelope (*A. leucophæa*) though formerly an inhabitant of the Cape colony, is now so rare in Southern Africa, that it is said no specimen has been killed there for more than thirty years. A very large species called the roan antelope *(A. equina)* was found by Mr Burchell among the mountainous plains in the vicinity of Lattakoo. The springer antelope *(A. euchore)* is called spring-bock by the Dutch. It inhabits the plains of Southern and Central Africa, and, during its migratory movements, congregates in such vast flocks as for a time utterly to destroy vegetation. The lion has been observed to accompany their onward journey, walking like a grizzly tyrant in the midst of a dense phalanx of these beautiful but fearful creatures, and with only as much space between him and his victims as the irrepressible terror of those immediately around him could obtain by pressing outwards. Mr Pringle calculated that he had sometimes within view not less than 20,000 at a time.

Among the more remarkable of the African antelopes are those called *guevei (A. pygmæa,)* which seem to consist of two well-marked varieties, if two distinct species have not been confounded under a single name. Of the smaller variety we remember a female in Mr Bullock's museum which scarcely exceeded the dimensions of a large rat, and its legs were no thicker than a goose's quill. The gueveis are generally brought from the coast of Guinea, although they have sometimes been observed to occur in the vicinity of the Cape of Good Hope. In illustration of another beautiful form of this varied genus, we have represented the species commonly called, from its peculiar markings, the harnessed antelope (*A. scripta*, Pallas, see Plate XIV., figure 1). It was seen by M. Adanson in the interior of Senegal, and few additions have been made to its subsequent history.

In the forests of Hindustan we find the *chickara* or four-horned antelope (*A. chickara*, see Plate XIV., figure 4). General Hardwicke informs us that this species inhabits woody and hilly tracts along the western provinces of Bengal, Bahar, and Orissa. It is described as a wild and agile creature, incapable of being tamed unless when taken young. It is about twenty inches in height, and two feet nine inches in length. The larger pair of horns are smooth, erect, slightly inclined forwards, somewhat divergent, and about three inches long. About an inch and a half in front of these arise a short stumpy pair, about an inch and a half in circumference, and scarcely an inch high.[2] A nearly allied, if not identical species, has been described by M. de Blainville under the title of *A. quadricornis*.[3]

The *nyl-ghau* (*Ant. picta* and *tragocamelus*, Gmel., Plate XIV., figure 3) departs greatly from the form of the true antelopes, and merges on that of the bovine tribes. Its eastern name signifies *blue ox*, and it is in fact never considered as an antelope by native observers, though so classed by European naturalists. This species was unknown to the ancients, and one of the first authentic notices of it is that by Dr Parsons.[1] Lord Clive transmitted a pair to England from Bombay in 1767, and these bred regularly for several years. The nylghau is not generally distributed over the Peninsula of Hindostan, but it occurs in the districts of Kamaghur in Central India, and is known to spread from thence to the foot of the Himmaleh Mountains. Bernier describes it as one of the objects of the chace which delighted the Mogul Emperor Aurengzebe, during his progress from Delhi to Cashmere. It is a treacherous animal, vicious, and full of vigour, and apt to prove a dangerous neighbour even in the domestic state. It may, however, be completely tamed.

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[1] For a summary of the species, with indications of the various sub-generic groups, by Colonel Hamilton Smith, see the *Synopsis of Mammalia*, forming the fifth volume of Griffith's *Animal Kingdom*, so frequently before referred to. For numerous important observations, and a great deal of general information regarding the antelopes, consult also the fifth volume of the same work.

[2] *Linn. Trans.* vol. xiv.

[3] *Journal de Phys.* Aout, 1818.

An antelope of a still more anomalous form is the *gnu* (*Ant. gnu*, Gmel., Plate XIV., figure 5). It appears as if it were compounded of various other species, being maned like a horse, with the limbs of a stag, and the horns of a buffalo. It forms, with the brindled gnu and another nearly related species, the genus *Catobeplas* of Colonel Smith, by whom it is arranged among the bovine tribes. It assembles in large herds in the southern deserts of Africa, but is not now found nearer the Cape than the Great Karoo district. The other species spread into the country of the Caffres, and the interior deserts.

We shall conclude our meagre notice of this great genus with the only species indigenous to the central countries of the European continent, the celebrated chamois, *Ant. rupicapra*, Linn. (See Plate XIV., figure 2.) This animal measures rather more than three feet in length, with a height of about two feet and a few inches. It is distinguishable from all the other species by its short smooth black horns, rising perpendicularly from the forehead, and suddenly hooked backwards at their extremities. It inhabits the lofty mountains of Switzerland, Piedmont, and Savoy, the Pyrenees, various parts of Germany, Greece, and some of the Mediterranean islands. The sterile valleys and broken rocky grounds in the vicinity of regions of perpetual snow, form the chamois' favourite places of abode. It is much sought after for the sake of its excellent flesh, and occasionally by amateur sportsmen on account of the exciting nature of its pursuit, carried on amid scenes of great wildness and sublimity, and not unattended by danger, from the rugged or precipitous character of the ground, the deceptive ravines of ice, and the falling masses of mountain snow.

As intermediate between the antelopes and the ensuing genus, we shall here place a species which has been dignified by a great variety of names, we mean the Rocky Mountain goat (*Aplocerus lanigera*, Smith, *Capra Americana*, Richardson), by some called the wool-bearing antelope. It inhabits the highest and least accessible summits of that great range of North American mountains from which it has derived its best known name. It is equal in size to a large sheep, its colour white, and its whole body, particularly the back and hinder quarters, covered by an ample coating of long fine wool, but greatly intermixed with coarser hair. The importation of this species into the alpine or insular districts of Scotland has been recommended as an interesting experiment, not likely to be attended by much difficulty, and which might probably lead to valuable results.[2] The precise extent of its territorial range has not yet been ascertained, but it is known to occur from the 40° to the 64° or 65° of north latitude. It is scarcely ever seen at any distance from the mountains, and is said to be less numerous on the eastern than the western slopes of its native range. Its flesh is rather hard and dry, and somewhat unsavoury from its musky odour.

GENUS CAPRA, Linn. Incisives $\frac{0}{8}$, canines wanting, molars $\frac{6-6}{6-6}$; $= 32$. Horns directed upwards and backwards, compressed, transversely furrowed, their nucleus communicating by means of cells with the frontal sinus. No lachrymal sinus, nor inguinal pores. Chin generally bearded. Outline of the face straight, or rarely convex. Two inguinal mammæ.

The species which constitute the goat genus, although of less elegant form than many of the antelope tribe, are yet not undistinguished by considerable ease and gracefulness of movement; and the rocky heights on which they are so often seen no doubt add to their picturesque and imposing aspect. Although extremely docile, and fond of being caressed by human associates, they yet cease not to retain a certain degree of independence not observable in other cattle. Considered intellectually, they hold a high station in the animal kingdom. Buffon has greatly embroiled the history of these and the allied genera, by supposing that the species called the boquetin (*Capra ibex*) was the origin not only of all our domesticated sheep and goats, but of the chamois and several other antelopes. His paradoxes were first exposed by Pallas,[3] who traced the separation of the goats from the antelopes on the one hand, and from the sheep on the other, and pointing out the various species of the first named genus, shewed that our domesticated kind was derived not from the ibex, but from another wild species called *ægagrus*, an inhabitant of the Caucasian Mountains. He admits, however, in relation to certain varieties, the probability of a cross with the ibex.

The wild goat (*Capra ægagrus*, Gmelin, see Plate XV., fig. 2), the admitted source of our domestic kinds, although believed by some to inhabit the Alps of Europe, is more distinctly known as a native of the mountains of Persia and the Caucasus, where it is known by the name of *paseng*, and from whence it spreads through a great extent of northern Asia to the frontiers of the celestial empire. It is also the *bezoar* goat of the oriental nations, so called from a peculiar concretion sometimes found in the intestines. The male is larger than the usual size of our domestic species, and his horns, which form an acute angle in front, with a rounded back, and transverse ribs, are nearly three feet long. The head is black in front, the beard brown, and the general colour of the body brown and grey, but varying with the season.

The semi-domesticated varieties are too numerous to be here described. Of these the most famous is the Cashmere breed, from the coat of which the celebrated shawls and other articles are manufactured. The fleece is long and of a silky texture, straight and white. The most esteemed is the produce of Thibet, from which country it is exported to Cashmere, where 16,000 looms are constantly employed, each affording occupation to three men, and yielding together about 30,000 shawls per annum. A single fine shawl, of a rich pattern, requires for itself about a year in making.[4] The Thibet variety is chiefly remarkable for the excessive length of its silky covering, which falls in ample clusters from each side of the back, with a dorsal line of separation, and measures above a foot and a half. Its general colour is brown, with the points of a golden fulvous hue. The males of both these eastern breeds have very large flattened wavy horns. They have been introduced alive to France and England.

A beautiful dwarf variety, originally from western Africa, and commonly called the Guinea goat, is also well known in this country. The goat of Angora resembles the Cashmere kind in its flowing fleece, the locks of which, however, instead of being straight, assume the form of beautiful spiral ringlets The *Jemlah goat*, an inhabitant of the highest

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[1] In the *Phil. Trans.* vol. xliii.

[2] *Wernerian Memoirs*, vol. iii. p. 306.

[3] *Spicilegia Zoologica*, fascic. xi.

[4] *Tour in the Upper Provinces of Hindostan.* By A. D. p 187.

Pecora.

Pecora.

range of central Asia, and that called *Jahral* in the Nepaul country, seem to present the characters of distinct species. The latter is bold, capricious, and irascible, but it is easily tamed, and thrives well when transported to other countries.[1]

The bouquetin of the European Alps (the stein-bock of the Germans, *Capra ibex*, Linn.) is a large, powerful, and extremely active animal, almost five feet in length, and nearly three feet high. The colour is greyish fawn-colour above, whitish below, with a deep brown line along the dorsal region. The female resembles the male, except in the diminished size of her horns. This species dwells among the highest and most precipitous peaks of the Alps of Switzerland, Spain, and other lofty ranges, far surpassing the chamois in the boldness with which it bounds from crag to crag, and ascending to perilous heights where even that alpine species is never seen. It is said, when springing from a great height, to bend its head between its fore-legs, in such a manner as to break its fall by alighting on its horns as well as hoofs. It is easily tamed when taken young, and breeds freely with the domesticated goats. It is alleged to do so, indeed, even in a state of nature,—for it is the general opinion of the shepherds of the Alps and the Pyrenees, that all the great he-goats which act as leaders to the flocks are either genuine bouquetins, or immediately descended from that powerful species. We believe that all that has been stated as to the occurrence of the paseng or *œgagrus* (we mean the true wild-goat) in Europe, owes its origin to the existence of a cross breed between the goat and bouquetin. The latter is likewise an Asiatic animal, and was seen by Pallas in the mountains of Siberia,[2] but the Caucasian ibex, described by Guldenstaedt is a distinct species.[3] The maned bouquetin of Africa, erroneously so called, is undoubtedly an antelope, figured by Mr Daniel under the title of *Takhaitze*.[4]

GENUS OVIS, Linn. Teeth as in the preceding genus. Horns thick, angular, transversely furrowed, spirally twisted in a lateral direction, the points more or less recurving forwards. Chin seldom bearded. Outline of the face arched or convex.

The leading fact in the geographical history of this genus is, that it occurs both in the New and the Old World, whereas the goat tribe are naturally unknown in America.

We cannot here enter into any detailed history of the numerous varieties of the domestic sheep which have resulted from the almost immemorial subservience of this animal to the human race, but must confine ourselves to a slight sketch of the features and characteristic habits of the several wild races which inhabit the different regions of the earth. Although this invaluable species is usually regarded by naturalists as being not only specifically but generically distinguished from the goat, we incline to think that the latter, or generic separation, is founded chiefly upon characters which have arisen from the influential power of man. In a state of nature, the sheep is scarcely less active or energetic than the goat,—its dimensions are fully greater,—its muscular strength at least equal, both in force and duration. It is also an alpine animal, fearless of crag and cliff, and dwells indeed by preference among the steepest and most inaccessible summits of lofty mountains. Among its native fastnesses it is seen to bound from rock to rock with inconceivable swiftness and agility.

We need scarcely remind the reader of the very ancient subservience of this species to the domestic uses of mankind. It is the first recorded creature in the Holy Scriptures, of such as owned the dominion of the human race. "And Abel was a keeper of sheep, but Cain was a tiller of the ground."[5] Sheep-shearing is also mentioned during very early times: "And it was told Tamar, saying, Behold thy father-in-law goeth up to Timnath to shear his sheep;"[6] while, at a later period, the festivities of the season were taken advantage of by Absalom to slay his brother Amnon: "And it came to pass, after two full years, that Absalom had sheep-shearers in Baal-hazor, which is beside Ephraim; and Absalom invited all the king's sons."[7] The domestication of the sheep thus appears to have been almost coeval with the creation of our own species, and continuous with its progressive descent. We may here mention that the goat appears to be the next in succession, as applied to the purposes of the human race; then oxen, asses, camels, and lastly horses. The first mention of the mule, though prior to that of the horse, is of too casual a kind to lead to any precise conclusion, as to its being then known as a beast of burden: "And these are the children of Zibeon; both Ajah and Anah: this was that Anah that found the *mules* in the wilderness, as he fed the asses of Zibeon his father."[8]

The most remarkable external change which domestication has produced on sheep, is the conversion, as it is commonly called, of hair into wool, or, to state the fact more accurately, the prodigious development of one of the constituent portions of the coat, and the decrease or disappearance of the other. All animals inhabiting a cool or temperate climate seem supplied with both a woolly and a hairy covering,—the former being usually short and close, and entirely concealed by the latter, on the length, colour, and texture of which the external appearance of most animals in a great measure depends. These two kinds of covering are very observable in bears and wolves, and also in the more peaceful races of wild sheep; and nothing like either a metamorphosis or a new creation is necessary to produce the remarkable alteration in the domestic breeds. Of these we here figure as an example the long-legged sheep of Africa. (See Plate XV., figure 1.)

The principal unsubdued races of the sheep are the following: the Mouflon or Musmon of Sardinia, Crete, and Corsica (*Ovis musimon*, Pall., *O. ammon*, Gmelin, *O. aries*, Desm.),—the bearded sheep of Africa (*Ovis tragelaphus*, Cuv., Desm.),—the Argali, or wild sheep of Asia (*Ovis ammon*, Linn., Desm.), and the Rocky Mountain sheep of America (*Ovis montana*, Richardson). These four quadrupeds differ greatly, in the first place, in their geographical position; and, secondly, in several of their external characters. The distinctive attributes of all the species have not been detailed with sufficient fulness and precision to enable us to say with certainty whether each differs specifically from the other, or is rather its natural representative under a different modification of climatic influences. However this may be, it is probable that from one or other of these unsubdued races our own domestic tribes have been derived, and we shall therefore present the reader with a brief sketch of their natural history.

Ovis musimon, Pallas. The Musmon.[9] (See Plate XV., figure 4.) This species measures about three feet and a half in length, and its height, at the highest part of the back, is about two feet six inches. The neck is large, the body thick, muscular, and of a rounded form. The limbs are robust, and the hoofs short. The horns of the male are nearly two feet long. The body is protected by a short, fine, grey-coloured wool, of which the filaments are spirally twisted, and by a stiffish silky hair of no great length, yet sufficient to conceal the wool beneath. The Musmon (under which name it was known to the ancients) inhabits the loftiest parts of Crete, Corsica, and Sardinia, the western mountains of European Turkey, the isle of Cyprus, and probably other islands of the Grecian Archipelago. It is not, however, supposed to occur in more northern countries, unless the identity of the species with the Siberian Argali should in time be demonstrated. It is mentioned as an inhabitant of Spain by Pliny, and according to Bory St Vincent, it still occurs among the mountainous provinces of the ancient kingdom of Murcia. It is gregarious in a state of nature, and seldom descends from the highly elevated portions of its insular mountains, of which the elevation and latitude, however, do not admit perpetual snow. About the month of December or January, the larger troops divide into less numerous bands, each consisting of a male and a few females. For a short time after this period, when the males encounter each other, fierce battle ensues, and one of the combatants is not unfrequently slain. The females carry their young for five months, and usually produce twins in April.

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[1] *Proceedings of Zoological Society*, part ii. p. 106.

[2] *Spicilegia Zoologica*, fascic. xii. p. 31.

[3] *Acta Petropolitana*, 1779.

[4] *African Scenery*, plate 24.

[5] *Genesis*, ch. iv. v. 2.

[6] Ibid, ch. xxxviii. v. 13.

[7] 2 *Samuel*, ch. xiii. 23.

[8] *Genesis*, ch. xxxvi. v. 24.

[9] *Mouflon* of Buffon and F. Cuvier,—*Ovis aries* (race sauvage considérée comme le type primatif) of Desm.

We have said that the question is still undetermined regarding the origin of our domestic breeds. The prevailing sentiment, however, is certainly in favour of the species just named. We know that the Corsican musmon brought to Britain by General Paoli, became the parent of a mixed progeny; and if Pliny is to be regarded in the light of an authority, the wild sheep of Spain frequently intermingled with the domestic race. The produce were known by the name of *umbri*. We may observe that all wild sheep have the chaffron greatly arched, and this peculiar form of the nasal bones is found to increase with the degeneracy of the domestic breeds.[1] Colonel Hamilton Smith seems to suspect that even the musmon itself may not be a genuine wild animal, but an African domestic breed once imported, and partially restored to its primitive characters, by the security afforded by its insular situation after it had accidentally escaped from the influence of man.

Ovis tragelaphus, Cuv. The bearded sheep of Africa.[2] The hair on the lower part of the cheeks and upper jaws of this species is extremely long, and forms a double or divided beard. The hairs on the sides and body are short, those on the top of the neck somewhat longer, and rather erect. The whole under parts of the neck and shoulders are covered by coarse hair, not less than fourteen inches long; and beneath the hairs on every part there is a short genuine wool,—the rudiments of a fleecy clothing. The tail is very short. The horns approach each other at their base, and are above two feet long, about eleven inches in circumference at the thickest part, and diverge outwards, the extremities being nineteen inches from each other. The size of this animal is differently stated by different authors, and some confusion has arisen in its history and synonymy from the want of accordance between figures and descriptions. It inhabits the desert steeps of Barbary, and the mountainous parts of Egypt. The specimen in the Paris Museum was shot near Cairo.

Ovis ammon, Linn., Desm. The Argali or wild sheep of Asia. The general colour of this species is fulvous grey, and white beneath, with a whitish disk upon the buttock. The wool lies as it were concealed beneath a close set hair. The adult male measures about three feet in height at the shoulder, and five feet in length. His horns are nearly four feet long, and fourteen inches in circumference at the base. They are placed on the summit of the head, so as to cover the occiput, and nearly touch each other in front, bending backwards and laterally, then forwards and outwards, their base being triangular, and their surface wrinkled. The female is of smaller size, and her horns are nearly straight. This species seems to have been confounded by most writers of the earlier portion of last century with the mouflon, a European species already noticed; and even Pennant and Shaw, in compiling its history, have amalgamated the accounts of two distinct kinds. Gmelin (the traveller[3]) and Pallas[4] have furnished us with the most accurate as well as ample details of its actual characters. It inhabits the mountains of Central Asia, and the elevated Steppes of Siberia, from the banks of the Irtisch to Kamtschatka. In the last named country, its flesh and fat are much esteemed. The horns are sometimes so large as to admit of young foxes taking shelter in their decaying cavities. The name of Argali applied by Pallas to this species, is the Mongolic title of the female. The male is called Guldschah. It is the Weissarsch of the ancient Germans, and in more modern times appears to have been first noticed by Father Rubraquis in the thirteenth century. He calls it *Artak*, most likely an erroneous reading for *Kirtaka*, which, according to Hamilton Smith, is one of its Tartaric names.

Ovis montana, Desm., Rich. The Rocky Mountain sheep, or American Argali. (See Plate XV., figure 6.) This animal exceeds the Asiatic kind in size, and is larger than the largest varieties of our domestic breeds. The horns of the male are of great dimensions, arising a short way above the eyes, and occupying almost the entire space between the ears, but without touching each other at their bases. The horns of the female are much smaller, and but slightly curved. The hair in this species resembles that of a deer. It is short, fine, and flexible, in its autumn growth, but becomes coarse, dry, and brittle, as the winter advances. The colours reside in the ends of the hair, and as these are rubbed off during the progress of winter, the tints become paler. The old rams are almost entirely white in spring. The Rocky Mountain sheep inhabits that lofty and extended chain of North America from which it derives its name,—from its most northern point in latitude 68°, to at least the 40th degree. Its flesh is delicious, exceeding, it is said, in flavour that of the finest English mutton.

GENUS BOS, Linn. Incisives $\frac{0}{8}$, canines wanting, molars $\frac{6-6}{6-6}$; $= 32$. Body large, limbs robust, muzzle broad, the facial outline nearly straight. Horns simple, conical, lunate, directed laterally, the points raised. Tail rather long, and terminated by a tuft of lengthened hair. Four mammæ.

Buffon appears to have admitted of only two kinds of cattle—the bull and the buffalo. A wild bull, the source of our domestic breeds, the aurochs of Europe, the bison of America, and the zebu of Africa and Asia, were all regarded by him as varieties of one and the same species, produced by climate, food, and domestication. The humped backs of the bison and the zebu, according to the imaginative views of the eloquent Frenchman, were signs of slavery produced by grossness and excess of feeding; and he sought to escape the dilemma presented by the existence of wild cattle with humped backs, by at once asserting that these were either an emancipated tribe, originally descended from an enslaved and deteriorated race, or constituted in themselves a natural variety, of which the hump was characteristic. According to the same authority, it was a humped variety, which, passing from the north of Europe to the American continent, gave rise to the bison breed of that country,—a theory which he deems strongly confirmed by the fact, that both the aurochs of the Old World, and its representative in the New, smell strongly of musk![5] So confused, indeed, were his notions regarding these animals, that he appears to have confounded the bison and the musk ox, although Charlevoix, and other travellers to whom he had access, had previously described the difference in their external characters, as well as in their haunts and habits. He advances the northern boundaries of the bison almost to the Pole itself; whereas, in reality, it is only the musk ox that is found there: and then, forgetting what he had just before stated, he locates the race of aurochs in the Frigid Zone, and restricts the bison to the temperate,—while he draws the general conclusion that all domestic cattle without humps are descended from the former, and all humped cattle from the latter.[1]

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[1] Griffith's *Animal Kingdom*, vol. iv. p. 323.

[2] *Mouflon d'Afrique*, Geof. St Hilaire. *Bearded sheep*, Pennant and Shaw. *Bearded argali*, Ham. Smith.

[3] *Voyage en Siberie*, t. i. p. 368.

[4] *Spicilegia Zoologica*, fascic. xi. p. 3. tab. 1.

[5] Bernard's *Buffon*, t. v. p. 100.

Though Pallas [2] refutes the mistake committed by Buffon in supposing that the aurochs of Europe consisted of two varieties—the urus and the bison—he himself falls into the equally gross error of confounding as identical the American and European species. He maintains the probability of the latter having passed from the Old World to the New, when the great northern continents were connected together by vast and continuous tracts of land, of which the shattered and sunken debris are still represented by the snow-covered mountains of Iceland, and the isles of Shetland and Feroe. He regards the aurochs as the original source of our domestic cattle, and both as synonymous with the bison of America,—while the musk ox of the New World, the grunting ox of the East, and the buffaloes of Asia and of Africa, are viewed as distinct from those just named, and from each other.

It thus appears that prior to the time of Cuvier the larger kinds of horned cattle were considered as amounting to *five* in number, so far as living species were concerned. But the great French anatomist speedily distinguished eight species.[3] He separated the aurochs from the bison, and established two additional kinds, the arnée of Asia, and the domestic bull, the source of which he traced not to the aurochs, of which the number of the ribs, the occipital arch, and the inter-orbital distances of the forehead, are dissimilar, but to a fossil species (probably by this time extinct in the living state), of which the bones occur in various alluvial soils of Europe. We shall here briefly notice the principal species of taurine animals.

Bos taurus, Plin. *Bos taurus, domesticus*, Linn. The domestic bull and cow. The most permanent and essential specific characters of this animal are the following: Forehead flat, higher than broad; horns round, placed at the two extremities of a projecting line, which separates the front from the occiput; ribs amounting to thirteen pair; teats disposed in the form of a square; hair of the anterior parts of the body not more bushy than that of the other portions. The original of this invaluable species is supposed to have been the *Urus* of ancient writers,—the *Thur* of the Polish nation, an animal which, from various accounts, appears to have borne a much closer resemblance to our domestic breeds, than do either the modern aurochs (commonly called the European bison) or the buffalo. It seems to have become almost extinct during the middle ages, in consequence of the progress of civilization among the western nations, and probably ceased to exist in a living state about the fifteenth century, except in a few of the royal forests of Poland. Herberstein and Martin Cromer state that the thur was to be found only in Massovia, near Warsaw, where it appears to have been kept as a curiosity, just as (according to Gilibert) the *zubr* or modern aurochs continues to be to this day. In the fossil skulls which seem to represent the urus, the horns are curved forwards and downwards; but in the countless varieties which constitute the domestic breed, these parts assume a great diversity of form and direction, and are sometimes altogether wanting. The ordinary races of the torrid zone (supposing the so called zebus to be descended from the same root) are generally distinguished by a hump or large excrescence of fat and flesh upon the shoulders.

We cannot here inquire, however briefly, into the history of our British cattle. The original introduction of "horned bestial" to our island, is neither known in history, nor asserted by tradition. Whether they were derived from abroad, or were descended from wild individuals of the urus race, native to Britain in former ages, are questions which the lapse of time will never solve, but rather tend to shroud in deeper darkness. The climate of the British Isles is, beyond most others, productive of a great variety in the nature of our pastures, and of a corresponding variety in the character and condition of such animals as depend on those pastures for support. Cæsar mentions the abundance of the British cattle, and adds, that we (that is the then inhabitants, for the present races, like the descendants of the animals in question, are a mingled breed) lived much on milk and flesh, to the neglect of tillage. Strabo praises our bountiful supply of milk, but denies to us the art of making cheese. This preference of a pastoral life over one of agriculture, was handed down to much more modern times, and prevailed throughout the continuance of our feudal government, the warlike services of which would have proved in a great measure incompatible with the prolonged and steady labours of tillage. In regard to the wild white cattle, commonly so called, which still exist at Chillingham Castle in Northumberland, at Wollaton in Nottingham, at Gisburne in Craven, at Chartly in Staffordshire, and at Hamilton in the county of Lanark, we shall merely mention that no sufficient evidence has ever been brought forward to prove that these are entitled to the character of an aboriginal breed. Fitz-Stephen, who lived in the twelfth century, speaks of the *uri sylvestres*, which in his time inhabited great forests in the neighbourhood of London, and at a later period (fourteenth century) King Robert Bruce was nearly slain by a wild bull, which attacked him "in the Great Caledon Wood," but from which he was rescued by an attendant, "whom he endowed," says Hollinshed, "with great possessions, and his lineage is to this day called of the Turnbulls, because he overturned the beast, and saved the King's life by such great prowess and manhood."[4] There is, however, a link wanting to connect these fierce creatures with the small and often hornless breed of white cattle still existing in the parks alluded to; and although the straightness in the backs of the latter animals, the fierceness of their dispositions, and their agreement in some particulars with the ancient unreclaimed breed of Britain, may afford a reasonable ground for conjecturing that they are identical with the primitive source of our domestic cattle; yet we are rather inclined to regard them as descended from the same source, than as constituting that source itself.

Bos urus, Gmelin, *Bos taurus*, var. *urus*, Linn. European Bison, or Aurochs of the Germans.[5] This species is frequently, though erroneously, regarded as the origin of our domestic cattle. "There is, I believe, no doubt," says Mr Bingley, "that the ox is a descendant of the bison, a large and powerful animal which inhabits the marshy forests and vales of Poland and Lithuania. In the lapse of many centuries, however, its general appearance, as well as its temperament and disposition, have undergone a radical change. The enormous strength of the body, the great depth of chest and shoulders, the shagginess and length of hair which covers the head, neck, and other fore-parts of the bison, as well as his savage and gloomy disposition, are in the present animal so altered that the mere variety would almost seem to constitute a distinct species."[1] This mistaken view of the subject has arisen from ignorance of the leading distinctive characters. The aurochs is distinguished by its bulged or convex forehead, which is, moreover, broader than high, by the attachment of the horns *below* the line of the occipital ridge, by an additional pair of ribs (fourteen instead of thirteen) by a sort of frizzled wool, which covers the head and neck, and forms a kind of beard or small mane upon the throat. The tone and utterance of its voice is also quite peculiar. It is a wild and independent animal, now confined to the marshy forests of Lithuania, of Carpathia, and the Caucasus, though formerly an inhabitant of the temperate parts of Europe. It is the largest of all the quadrupeds native to the European continent, measuring six feet in height at the shoulder, and betwixt ten and eleven feet in length, from the nose to the insertion of the tail. According to Gilibert, it far surpasses the largest of the Hungarian oxen. The horns are black, and thicker and more compact than those of the domestic bull. In both sexes the lips, gums, palate, and tongue, are blue, and the last named part is very rough and tuberculated. Certain portions of the hide have decidedly a musky smell, especially during the winter season; and the name of Bison is supposed to have been bestowed upon it in consequence of that peculiar odour,—from the German word *wisen* or *bisem*, which signifies musk. The name of Aurochs is probably synonymous with that of *Urus*, originally applied to another species.

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[1] Bernard's *Buffon*, t. v. p. 89.

[2] *Acta Petropolitana*, t. ii.

[3] *Diction. des Sciences Nat.* article *Bœuf*. The same amount of species (including the musk ox, *Ovibos moschatus*) is given in the last edition of the *Règne Animal*, but the *Arnée* of Asia is not there admitted as distinct.

[4] See a more detailed account in the *Cosmographe and Description of Albion*, prefixed to Bellenden's Translation of Boethius's *History and Chronicles of Scotland.* Tait's reprint, chap. x. p. 39.

[5] This is the *bison* of the ancients, the Bœuf aurochs of Desmarest. called *Zubr* by the Poles.

Bos bison, Linn. *Bos Americanus*, Gmelin. (Plate XV., figure 3.) The Bison of the New World, or buffalo of the Anglo-Americans. The head of this species resembles that of the preceding, and the anterior portions of its body are in like manner covered by a curled woolly hair, which becomes excessively long during the winter season; but its legs are shorter, its hinder extremities comparatively weaker, and its tail not nearly so long. It is said to have fifteen pair of ribs. It inhabits a great extent of territory throughout the temperate and northern parts of North America, and its history is so fully described by many modern authors, that we need not here dilate upon it.

Bos bubalus, Linn. The Buffalo properly so called. (Plate XV., figure 5.) The forehead of this animal is convex or bulging, higher than broad, the direction of the horns is lateral, and they are marked in front by a longitudinal projecting line. It is originally a native of India, from whence it was brought into Egypt and Greece. It was introduced into Italy about the close of the sixth century, and now grazes in numerous herds among the Pontine Marshes. Its milk is excellent, its hide extremely strong, its flesh but slightly esteemed.

Bos gavæus, Ham. Smith. *Bos frontalis*, Lambert. The *Gayal* of the Hindoos. Nearly of the size and form of the English bull, with a dull and heavy aspect, but in reality almost equalling the wild buffalo in activity and strength. Its horns are short, slightly compressed, thick though distant at the base, and rise directly outwards and upwards in a gentle curve. From the upper angles of the forehead proceed two thick, short, horizontal processes of bone, covered by a tuft of light coloured hair. There is no hump upon the back, but a sharp ridge runs along the hinder part of the neck and shoulders, and anterior portion of the dorsal region. This species inhabits the mountain forests to the east of Burrampootra, Silhet, and Chatgoon. The milk, though rich, is neither lasting nor abundant. The gayal has been domesticated in India, and is venerated by the Hindoos. The female has been known to produce with a common zebu bull of the Deswali breed.

Bos grunniens, Pallas. The Yack, or grunting ox,—*Soora Goy* of the Hindostanese. Occiput convex, and covered with frizzled hair; horns round, smooth, pointed, lateral, bending forwards and upwards; withers very high, but not so decidedly hunched as in the zebus; mammæ four, placed transversely; fourteen pair of ribs; hair on the neck and back woolly,—very long upon the tail. This species dwells among the mountainous regions of Central Asia, and produces the *horse-tails* (commonly so called), used as standards by the Turks and Persians. The *chowries*, or fly-drivers, made use of in India, are likewise formed from the tail of the grunting-ox. It is dyed red by the Chinese, and worn as a tuft to their summer bonnets.[2] The animal is domesticated by the Mongolians and by the Tartar tribes. Though not large boned, it looks bulky, owing to its long and ample coat of hair. It has a downcast heavy look, is sullen and suspicious, and usually exhibits considerable impatience on the near approach of strangers. It is sure-footed, and capable of carrying a great load as a beast of burden, but is not employed in agriculture.[3]

Bos Caffer, Sparmann. The Cape Buffalo,—*Qu'Araho* of the Hottentots. This species is characterized by dark rufous horns, spreading horizontally over the summit of the head, with the beams bent down laterally, and the points turned upwards. They measure from eight to ten inches broad at the base, and are divided from each other only by a slight groove. They are extremely heavy, cellular near the root, and measure five feet in extent, following the curved line from tip to tip. The hide of the Cape buffalo is black, and, especially in old animals, almost naked. Its tail bears a tuft of bristles at the end. It is a gregarious animal, dwelling in small herds in the brushwood and open forests of Caffraria, and striking accounts of its strength and ferocity are recorded in the writings of Sparmann and Thunberg. Like most of the genus, it is sometimes capable of being excited almost to madness by any thing of a red colour. It swims with surprising force and agility.

Bos moschatus, Gm. The Musk Ox,—*Ovibos moschatus*, De Blainville. This singular animal inhabits many districts of America to the north of the sixtieth parallel. We owe our first systematic knowledge of it to Pennant, who received a specimen of the skin from the traveller Hearne;[4] but it had been previously mentioned, though vaguely, by several of the early English voyagers, and M. Jeremic had imported a portion of its woolly covering into France, from which stockings more beautiful than those of silk were manufactured. When full-grown, the musk ox is about the size of our small Highland breed of cattle. Its carcass, exclusive of the offal, weighs about 300 pounds. Its flesh, when in good condition, is well flavoured, resembling that of the rein-deer, but coarser grained, and smelling strongly of musk. The horns are remarkably broad at their bases, and cover the brow and crown of the head, where they come in contact with each other. The nose is blunt, the muzzle not naked as usual, but covered with short close-set hairs, and the head is large and broad. The legs are naturally rather short, and this dumpy character is increased by the great length of the hair upon the body, which hangs down almost to the ground. The horns of the cow are smaller than those of the male, and do not touch each other at their bases, and the hair on her throat and chest is shorter. The musk ox spreads over a great extent of the barren arctic regions. It visits Melville Island (north lat. 75°) in the month of May, but does not, like the reindeer, extend to Greenland and Spitzbergen.

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[1] *British Quadrupeds*, p. 391.

[2] Turner's *Account of an Embassy to Thibet*, p. 86, pl. 10.

[3] This species is no doubt the *Poephagus* of Ælian. It is curiously described in the old English translation of Conrad Gesner. See *The History of Four-footed Beasts and Serpents*, collected by Edward Topsel, 1658.

[4] *Arctic Zoology*, vol. i. p. 11.

Besides the eight species now enumerated, the Asiatic arnee (*Bos arnée*), and several other animals, either distinct in kind, or constituting well marked varieties of horned cattle, have been described both by travellers and systematic writers.[1]

The following is a summary of the geographical distribution of the principal species. Two are proper to North America,—the musk ox (*B. moschatus*), which dwells within the polar circle, and the bison (*B. Americanus*), which inhabits from that circle southwards, till between the 40° and 35° of north latitude. A like number is characteristic of Europe, viz. the aurochs or European bison (*B. bison*), called zubr by the Poles, and the genuine bull (*B. taurus*), the thur of the middle ages, and urus of the ancients, now extinct in the natural state. There are at least four species found in Asia,—the yak or grunting ox (*B. grunniens*), the common buffalo (*B. bubalus*), the arnee (*B. arnée*), and the gayal (*B. gavæus*). Only a single well-determined species inhabits Africa, the Cape buffalo (*B. caffer*). In relation, then, to the localities of species, it thus appears that the zone inhabited by the genus *Bos* stretches obliquely across all climates; and that each species, with the exception of the bull and buffalo, now reduced to universal slavery, and widely extended from their original centres through the dominating influence of man, is confined within certain circumscribed limits, in which it is retained as well by natural barriers as by instinctive inclination. The difference in the habits of life observable between the American and European bisons would of itself have sufficed to establish the specific distinction of these animals. Had they been identical, the aurochs or European species would have preserved in America that love of retirement which induces it to dwell in the central solitudes of forests, where (in that of Hercynia) it was found in the days of Cæsar, as it now is in those of Lithuania, or amid the loftier gloom of the Carpathian Mountains. The American bison, on the contrary, congregates in large troops, and delights to dwell in those open plains or prairies which produce a thick and abundant pasture. The musk ox, without avoiding such stinted forests as the sterile regions to which it is native are capable of producing, yet dwells for the greater portion of the year among the rocky and almost ice-covered mountains of the extremest north, "creating an appetite under the ribs of death," with, we fear, but little wherewithal to appease that appetite after it has been created. The buffalo (of Asiatic origin) is an animal of almost amphibious habits, fond of the long, coarse, rank pasture which springs up so speedily in moist and undrained lands. Hence its love of the Pontine marshes, where, according to Scaliger, it will lie for hours submerged almost to the muzzle,—an instinctive propensity which it is seen equally to exhibit in the Island of Timor. The yak inhabits elevated ranges, and the cool and lofty table lands of central Asia, while the buffalo of the Cape delights to dwell in the dense forests of Southern Africa. All these species, with the exception before named, may be regarded as the aboriginals of the countries where they now occur.[2]

ORDER VIII.—CETACEA, CUV.

We now come, finally, to the Cetacea, or whale tribe, which has usually been placed as the last in our systematic works; and very naturally, as these animals differ greatly from those of the preceding orders, in being inhabitants not of the land, but solely of the water; and though formed internally on the same general plan as quadrupeds, they have yet been adapted alike admirably and wonderfully, to all their exigencies as dwellers in the "great deep." The naturalist knows that their structure distinguishes them widely from the whole of the finny race (or fishes properly so called), and allies them closely to quadrupeds, and with these last, therefore, he associates them; whilst mankind in general, judging from their external appearance, allies, or rather identifies them with the class of fishes. Their marked peculiarities, then, arising chiefly from the adaptation of their structure to the watery element they inhabit, might well require from us more ample details than our nearly exhausted space will now allow. The great interest, however, as well as importance, of this branch of the subject, and the acquisition of materials recently derived from foreign sources, not yet available to the English reader, induce us to enter into some details. The scientific naturalist need scarcely be reminded of the extremely superficial manner in which this extraordinary order has hitherto been treated in all our compendiums of general knowledge.

The Cetacea are characterized as Mammalia without posterior extremities,—even the bones of the pelvis being scarcely represented by two small rudimentary ones, which hang suspended in the softer parts; the body is pisciform, with the tail cartilaginous and horizontal. The anterior extremities assume the appearance of fins, or swimming paws (as they have been more appropriately designated), having the bones flattened and short. They reside constantly in the water; but, as they breathe by lungs, they are obliged to ascend to the surface at frequent intervals for the purpose of respiration. Their blood is warm; they are viviparous; their mammæ are in some pectoral, though in most abdominal.

The Cetacea are arranged in two great divisions, viz. the *Herbivorous* and the *Ordinary* Cetacea.[3]

DIVISION I.—CETACEA HERBIVORA.

The *Herbivorous Cetacea* of Cuvier; also known as the *Sirenia*,—and popularly as *Tritons*, *Mermaids*, *Sea-cows*, &c.

The characters of this division are as follows:—Head not distinguished from the body by a neck; no blow-holes on the head, but nostrils on the snout; body pisciform; no dorsal fin; tail horizontal; pectoral fins resembling swimming paws; mammæ pectoral; skin nearly destitute of hairs; teeth very peculiar, but adapted only to a herbivorous regimen.

Until the present century the herbivorous Cetacea were intermingled with the seals or sea-dogs, and the walrus or sea-horse; but from these they are very decidedly distinguished by the total absence of every vestige of posterior extremities, so that the inferior half of the body is but little different from the ordinary Cetacea. From these latter again they differ in having no blow-holes on the summit of the head, but nostrils much resembling those of several quadrupeds. Although wholly aquatic, they do not, like the majority of the other Cete, feed upon fish, and hunt them through the wide ocean, but they live solely upon vegetables, and these such as are supplied by the shallows of the sea, its estuaries, and the banks of rivers. Hence it is, and also from a general resemblance in the upper parts of the body, that they have so generally received the names of sea-calves and sea-cows.

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[1] See particularly the Memoir by Col. H. Smith in Griffith's *Animal Kingdom*, vol. iv.

[2] Consult M. Desmoulins' *Memoire sur la Distribution geographique des Animaux Vertebrés, moins les Oiseaux*, in *Journal de Physique*, Fevr. 1822; Baron Cuvier's *Ossemens Fossiles*, t. iv. the article *Bœuf*, in the *Diction. Classique d'Hist. Nat.*; and Mr Wilson's third *Essay on Domestic Animals* in the *Quarterly Journal of Agriculture*, No. viii.

[3] We owe much to the excellent work of Camper, entitled, *Observations Anatomiques sur la Structure Interne et le Squelette de Cetacés*, with notes by Cuvier, 4to, Paris, 1820. The remarks of Dr Scoresby, in his various publications on the Arctic regions, have greatly enriched this branch of zoology. The *Histoire Naturelle* of Lacépède contains good remarks, but the plates are generally execrable.

There can be no doubt that these Cete, in most instances, formed the type of those ideal objects of ancient poetry, the tritons, half men and half fish, who had power to calm the stormy surge; and probably too of the sirens, those sea nymphs whose melody charmed the entranced voyager to his destruction and death. Without, however, dwelling on these well known figments, we shall, in a few words, state the more modern fancies, especially those of the northern races, regarding this peculiar group. "Beneath the depths of the ocean, an atmosphere exists adapted to the respiring organs of certain beings resembling, in form, the human race, who are possessed of surpassing beauty, of limited supernatural powers, and liable to the incident of death. They dwell in a wide territory of the globe far below the region of fishes, over which the sea, like the cloudy canopy of our sky, loftily rolls, and there they possess habitations constructed of the pearly and coralline productions of the ocean. Having lungs not adapted to a watery medium, but to the nature of atmospheric air, it would be impossible for them to pass through the volume of waters that intervenes between the submarine and the supramarine world, if it were not for the extraordinary power of entering the skin of some animal capable of existing in the sea. One shape that they put on, is that of an animal human above the waist, yet terminating below in the tail of a fish; and thus possessing an amphibious nature, they are enabled not only to exist in the ocean, but to land on the shores, where they frequently lighten themselves of their sea dress, resume their proper shape, and with much curiosity examine the nature of the upper world that belongs to the human race."[1]

A knowledge of the existence of such legends is almost necessary to account for the effects which have been usually produced by an encounter with these far-famed, but slightly known animals. We shall here adduce only a single relation of the supposed appearance of a merman, and another of his fair companion. Three sailors being in a boat, about a mile from the coast of Denmark, near Landscrone, observed "something like a dead body floating in the water, and rowed towards it. When they came within seven or eight fathoms, it still appeared as at first, for it had not stirred; but at that instant it sunk, and came up again almost immediately in the same place. Upon this, out of fear, they lay still, and then let the boat float, that they might the better examine the monster, which, by the help of the current, came nearer and nearer to them. He turned his face, and stared at the men, which gave them a good opportunity of examining him narrowly. He stood in the same place for seven or eight minutes, and was seen above the water breast-high: at last they grew apprehensive of some danger, and began to retire; upon which the monster blew up his cheeks, made a kind of roaring noise, and then dived from their view. In regard to his form they declare, in their affidavits, that he appeared like an old man, strong-limbed, and with broad shoulders; but his arms they could not see. His head was small in proportion to his body, and had short curled black hair, which did not reach below his ears; his eyes lay deep in his head. About the body, and downwards, the merman was quite pointed like a fish."[2] Again, in 1823, "The crew of a fishing-boat, when at the deep-sea fishing, above thirty miles from land, upon drawing their lines, were not a little surprised to find that they had hooked by the back of the neck, and brought alongside, an animal of a singular aspect. They mustered resolution enough to take it into the boat, and keep it for some time: but on perceiving its pectoral mammæ, and on seeing it gasp, certain superstitious fears as to its being unlucky to kill a mermaid prevailed, and in an evil moment they slipped it overboard. On hearing of the circumstance, Sir Arthur Nicolson of Lochend, a most intelligent Shetland proprietor, and justice of the peace, called the men, three in number, put them on oath, and took down their description of the animal. The animal seems to have been a female, the mammæ being described as prominent and full. The skin was smooth and slimy; light grey on the back, and pure white on the belly. The swimming-paws terminated in webbed fingers. The eyes were small and of a blue colour; the neck remarkably short. The length was estimated at more than three feet, the largest circumference about two feet and a half. From the middle, the body tapered rapidly towards the tail, which was horizontal, and of a semicircular shape."[3]

Some of these animals have a voice, which, in certain circumstances at least, is interesting. In proof of this we shall allude to an incident mentioned by Captain Colnett as having occurred in his voyage to the Pacific, off the coast of Chili. "When in latitude 24° south," he says, "a very singular circumstance happened, which, as it spread some alarm among my people, and awakened their superstitious apprehensions, I shall mention. About eight o'clock in the evening, an animal rose alongside the ship, and uttered such shrieks and tones of lamentation, so like those produced by the female human voice when expressing the deepest distress, as to occasion no small degree of alarm among those who first heard it. These cries continued for upwards of three hours, and seemed to increase as the ship sailed from it. I never heard any noise whatever that approached so near those sounds which proceed from the organs of utterance in the human species."[4] It is, of course, such occurrences as these that have given origin to the many poetical effusions which we so often hear conjoined with all the charms of song.

> "What fairy-like music steals over the sea,
> Entrancing the senses with charm'd melody,
> 'Tis the voice of the mermaid that floats o'er the main,
> As she mingles her song with the gondolier's strain."

But it is now time to leave the regions of fiction and of superstitious exaggeration, and to present a sober, and, so far as ascertained, a correct view of this interesting group. It is now divided into three genera, and about twice as many species. There is first the genus *Manatus*,—the manatee of the West Indies; then the *Halicore*, or Dugong of the East Indies; and, thirdly, the *Stellerus*, an inhabitant of the polar regions. Of each of these genera it is on good ground supposed, that there are several species, which, however, still remain to be demonstrated. Of the *Manatus* there are not above two or three living species accurately ascertained, and as many which belonged to a former era of the world's history. Of the *Dugong*, so highly prized in the Eastern World, only one species is correctly known, and this chiefly through the zeal and energy of the late Sir T. S. Raffles when Governor of Batavia. For our knowledge of the manatus we are mainly indebted to the Duke of Manchester, who held the corresponding station in Jamaica. Of the *Stellerus* also, a name derived from the indefatigable naturalist of the expedition of the celebrated Behring, only one ascertained species is known. But let us proceed to the details.

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[1] Hibbert's *Shetland Islands*, 4to, p. 566.

[2] Pontoppidan's *Nat. Hist. of Norway*, p. 154.

[3] *Edin. New Phil. Journal*, vol. vi. p. 57.

[4] *A Voyage to the South Atlantic, &c.* Lond. 1792.

GENUS MANATUS, Cuv. *Trichechus*, Linn. The manatus, as its name implies, derives its principal generic character from its swimming paws. These, as in the other genera, are formed of soft parts and a membrane, which envelope the bones of the hands and fingers; but in the manatus four flat nails are also seen, which are attached to the edge of the fin. The tail is no less characteristic; it is long, extending to about one-fourth of the body, and oval-shaped, which gives the animal some resemblance to an otter.

The first species we notice is the *Man. Americanus* of Cuvier, Desmarest, &c. (See Plate XV., figure 1.) Head conical; no neck; muzzle large and fleshy, semicircular at its upper part, where are the nostrils; upper lip full and cleft in the middle; two tufts of stiff bristles are situated at its sides; lower lip much shorter; mouth not very large; skin of a greyish colour, with a few slender hairs scattered here and there; pectorals long, large, and oval, terminated by four flat nails. Length twenty feet. Vertebræ, according to Baron Cuvier, six (cervical), sixteen (dorsal), twenty-four (lumbar and caudal), in all forty-six. According to the late Sir E. Home, seven, seventeen, twenty-four, in all forty-eight. There is a corresponding difference between these authors as to the number of the ribs, which are peculiar, being almost round, and very large and thick. So also with the teeth, which, according to Cuvier, are $\frac{9-9}{9-9} = 36$; and to Home $\frac{6-6}{6-6} = 24$. Two incisives appear in the very young, but speedily drop out.[1]

Their manners and dispositions are stated by voyagers to be inoffensive, mild, and even amiable. Buffon states that they are both intelligent and sociable, not naturally afraid of man, but rather free to approach him, and to follow him with confidence and promptitude. But they have especially a kindly feeling for their fellows. They usually associate in troops, and crowd together with the young in the centre, as if to preserve them from all harm; and, when danger besets them, each is willing to bear his share in mutual defence or attack. When one has been struck with the harpoon, it has been noticed that the others will attempt to tear the dreadful weapon from the wounded flesh. When the cubs are captured, the mother becomes careless of her own preservation; and, should the mother be the victim, the young follow her fondly to the shore, where they are speedily secured and slain. Buffon also tells us that Gomara reared one in a lake in St Domingo, and preserved it for the long period of twenty-six years. It became so tame and familiar as to answer to its name, and took pleasantly whatever nourishment was offered.

The manatus is not found in deep waters. It frequents the shallow bays among the West Indian islands, and the sheltered creeks of the South American continent, particularly of Guiana and the Brazils. It was chiefly at the mouths of those vast rivers the Oronooko and the Amazons, "where ocean trembles for her green domain," that innumerable flocks of these cetacea were in use to dwell. They also ascended the fresh-waters for many hundred miles, entered many of their tributary streams, and peopled the interior lakes with their fantastic forms. The historian Binet has remarked, that, in his time, there were certain places within ten or twelve leagues of Cayenne where these creatures so abounded that a large boatful could be procured in a day; and, according to Barbot, the inhabitants of Cayenne were in the habit of sending brigantines to various localities to buy them from the Indians, who, for beads and toys, and iron tools, would fill their vessels. But the high estimation in which their flesh was generally held, and the avidity with which they were pursued, led ere long to a vast thinning of their numbers, in those countries which are thickly inhabited. They have retreated before the tide of population; and, wherever men are numerous, there they become scarce and shy, and, it is alleged, more fierce and vindictive in their disposition.

M. Senegalensis, Adanson, Cuv., Desm. This species, which frequents the rivers and shores of Western Africa, so much resembles the former in general appearance, and so little is explicitly known about its habits, that we shall merely adduce its characters. The bony cranium is somewhat shorter, in proportion to its breadth, than that of the preceding. Breadth of nasal foramina three-fourths of their length; the inferior margin of the lower jaw is curved, while it is straight in the *Americanus*. Length seldom more than eight feet. Dr Harlan published an account of what he considered another Manatus (he names it *latirostris*), the bones of which were found in great numbers on the banks of the rivers of the Floridas.[2] Cuvier discovered several fossil bones belonging to this genus, on which we do not now insist; and shall only further add, that the best informed naturalists suppose that several other living species still remain to be described.

GENUS HALICORE, Illiger, Cuvier, Desm. *Dugungus*, Lacép. There seems little doubt that of this genus also several species, inhabitants of the Eastern Seas, exist. It is a popular belief of the Malays that two species frequent their coasts; and M. Fr. Cuvier states, that there are considerable differences between the Malay varieties, and one which had been procured from the Philipines. It would appear also that an analogous animal is known on the coast of New Holland, which is supposed by MM. Quoy and Gaimard to differ from those of the Indian Archipelago;[3] and finally, a species which has been recently observed by Dr Ruppel in the Red Sea, does not agree with any of the preceding. But concerning all these species (with one exception), we have little, or rather no accurate information.

H. Indicus or *Dugong*, Desm.; *Trichechus Dugong*, Linn.; *Halicore dugong*, Cuv. As late as the year 1820, it was stated by Sir E. Home in the Royal Society, and correctly, that no specimen of the Dugong of full size had ever been seen by any one who was conversant with comparative anatomy. In the year above named Sir Everard read two papers upon it, and Sir Thomas S. Raffles transmitted an interesting memoir from Sumatra. About the same time Messrs Diard and Duvaucel sent both accounts and specimens to France, which brought it under the inspection of Baron Cuvier, who gave the result of his observations in his *Oss. Fossil.* t. v. p. 261. From these sources we supply the following description.

The head is small; the nostrils are situated in the summit of the upper jaw, where it makes a curvature downwards, and they penetrate in such a manner that the upper semilunar edge, pressing upon the lower surface, forms a perfect valve, which is shut when the animal is feeding at the bottom of the sea. The eye is very small, and is supplied with a third eyelid; the aperture of the ear is so minute that it is with difficulty perceived. The upper lip is large, forming a vertical kind of snout, like a short proboscis, which is studded over with a few bristles; the lower lip is much smaller, and the interior of the cheeks is covered with coarse hair. The skin is smooth and thick, and yields no oil, the colour bluish above and white underneath. The swimming-paws present no appearance of nails, but are somewhat verrucose on their anterior margin. The tail is broad, horizontal and crescent-shaped. The total length is twelve feet reaching to twenty when fully grown. The skull is remarkable for the very peculiar manner in which the anterior part of the upper jaw is bent downwards, almost at a right angle, so as to form a kind of beak; the lower jaw is truncated so as to correspond with the upper. These peculiarities are well seen in the skeleton, which on this and other accounts is worthy of examination. (See Plate XVI., figure 2.) The dental apparatus is very peculiar. Besides the incisors and molars, there are two great tusks in the upper jaw, which are scarcely covered by the lip. Concerning the true history of the teeth, there is still considerable discrepancy. It would appear that the first incisors soon fall out, and that the second set remain rudimentary, having their place supplied by an extremely firm horny-looking substance in both jaws. The number of molars varies from five or six in the young, to two in the old, and these do not drop out and disappear as in most other animals, but, on the contrary, those nearest the front are necessarily pushed forward, and when nearly worn away, are pushed out by those behind, as occurs in the elephant. The vertebræ are seven cervical, eighteen dorsal, and twenty-seven caudal, in all fifty-two; ribs eighteen pair.

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[1] See *Ossemens Fossiles*, t. v, and *Phil. Trans.* for 1821.

[2] See *Philad. Journal of Nat. Sciences*, vol. iii. 390, Lesson's *Manuel de Mammalogie*, and Fred. Cuvier's work entitled *De l'Histoire Naturelle des Cetacés*. Paris, 1836.

[3] *Zoologie du Voyage de l'Uranie*.

"The greatest peculiarity," says Sir E. Home, "in the structure of this animal, is that of the ventricles of the heart being completely detached from one another. This is not met with in any other animal."[1] Though this last statement is not strictly true, yet the structure is so peculiar that we have copied the excellent representation of it which Sir E. supplied to the Royal Society. (See Plate XVI., figure 4.) This sketch will represent the form which is common to the Dugong and the Stellerus, as will presently be seen; and which, so far as we know, has not been observed in any other animals. The following considerations, supplied by Sir E., are also interesting. "The skeleton may be compared to a boat without a keel, with the bottom uppermost, so that in the sea the middle part of the back is the highest point in the water; and as the lungs are extended to a great length close to the spine, they make the animal buoyant, so that when no muscular exertion is made the body will naturally float in a horizontal position. When we consider that this is the only animal yet known (with its congeners) that browses at the bottom of the sea unsupported by four legs, we must admit it will require a particular mode of balancing its body over the weeds on which it feeds; and in this way the centre of the back forms a point of suspension, similar to the fulcrum of a pair of scales, and the jaws are bent to correspond with this formation."[2]

The food of the Dugong appears to consist exclusively of the fuci and submarine algæ, which it finds at the bottom of the inlets of the sea. It browses on these vegetables precisely as a cow in a meadow, rising every now and then to respire. Its flesh resembles young beef, and is very delicate and palatable.

The Ikan Dugong is considered by the Malays as a royal *fish*, and the king is entitled to all that are taken. The flesh is by them considered as superior to that of the buffalo or ox. They distinguish two varieties. The breasts of the adult females are said to be large. The affection of the mother for its young is strongly marked; and the Malays make frequent allusion to this animal as an example of maternal affection. When they succeed in taking the offspring they feel themselves certain of the mother. The young have a short sharp cry, which they frequently repeat, and it is said that they shed tears. These tears are carefully preserved by the common people as a charm, the possession of which is supposed to secure the affections of those to whom they are attached, in the same manner as they attract the mother to her young. This idea, says Sir T. S. Raffles, is at least as poetical, and certainly more natural, than the fable of the Siren's Song.[3]

The last genus of the Herbivorous Cetacea is that called STELLERUS. The only known species was met with in the Northern Pacific, and being regarded by Steller as a species of Manatus, it received the appellation of *Trichechus Manatus borealis*. Cuvier, however, soon perceived that it was necessary to distinguish it as a distinct and peculiar form.

Stellerus borealis, Cuv., Desm.; *Manatus*, Steller, Pennant; *Trichechus Manatus borealis*, Linn.; *Rytina*, Illiger. This is a huge animal, reaching to the length of 26 or 28 feet. The skin is black, like the bark of an old oak; the head is small, and of an elongated form, with white moustaches, four or five inches long; the nostrils are situate at the end of the snout; the swimming-paws are beneath the neck, and serve for grasping as well as locomotion; they are terminated by a callosity, and have no nails; the tail is very broad but not long; the eyes are small, and can be covered by a cartilaginous membrane, which forms a third eyelid; the mouth is small, and has no proper teeth, but is furnished with two considerable bony-looking, but really horny masses, in their nature approximating to whalebone, one in the upper, the other in the lower jaw, not implanted into the maxillaries, but adhering to them. The vertebræ are 6, 19, 35, = in all 60.

The skin of this extraordinary creature is ragged and knotty. In fact, according to Cuvier, the scarf-skin is a kind of bark composed of fibres or tubes closely packed, perpendicular to the skin. These fibres are implanted into the true skin by small bulbs, so that when the epidermis is pulled off, the skin is remarkably rough and almost shaggy. As may be supposed, it has no hairs upon it, for the fibres themselves are nothing less than the hairs soldered together, forming a kind of cuirass. In a word, the animal is completely clad in a substance similar to the hoof of cattle. This hide is an inch thick, and so hard as scarcely to be cut with an axe; and when cut, it appears in the inside like ebony. This skin is of singular use to the animal during the winter, in protecting it against the ice, among which it feeds, and the sharp-pointed rocks, against which it is often dashed by the dreary tempest; and, during summer, in screening it from the rays of the never setting sun. The lips are double, that is to say, there are external and internal lips; and when approximated the space they circumscribe is filled by a thick mass of strong bristles, which are white, and an inch and a half long. These bristles in their nature, and still more in their function, agree with the baleen of the whalebone whales, serving as a sieve through which they can strain the water in which they feed, whilst they retain the food itself. The masticating apparatus is not less singular, and seems peculiar to this animal. It is not composed of teeth (of which we have already said there are none), but of two large white horny substances, forming dental masses, one of which adheres to the upper, and the other to the lower jaw. Even their insertion is peculiar, for they are not implanted into the bones beneath, after the manner of teeth, but only adhere to them by numerous pores and rugosities, corresponding to other projections and cavities in these bones. The substance itself has lately been discovered to be wholly horny, or composed of fibres agglutinated to each other, like the horn of the rhinoceros, and, when examined by the microscope, it is seen to consist of tubes. This structure is so singular that we have exhibited on Plate XVI., figure 3, the so styled tooth. A is the tooth itself, and *a*, *b*, *c*, *d*, *e* are the fibres or hairs, variously magnified, and viewed horizontally and vertically. These investigations have been made by M. Brandt, from a preparation in the Petersburgh Museum, and they are narrated in the Memoirs of its Academy, sixth series, vol. ii. But we must conclude these interesting details by Steller's account of the heart. This organ does not taper from the base to the apex, there to terminate in a single point, but it ends in two distinct and separate apices, corresponding to the two ventricles; the separation reaches to about one-third of their extent, at which place they unite, and then assume the usual appearance exhibited by the organ.

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[1] *Phil. Trans.* 1820, p. 319.

[2] *Ibid.* 1821, p. 269.

[3] The Dugong of the Red Sea was observed by MM. Hemprich and Ehrenberg, but we owe its more detailed description to Edward Ruppel—(*Museum Senckenbergianum*, t. i. tab. 6). He deems it different from that of the Indian Seas, and has named it *Halicore tabernaculus*, in consequence of his historical researches having led him to the conclusion, that it was with the skin of this species that the Jews of old were compelled by the Mosaic law to veil their tabernacle. The Hebrews named it *Thaachasch*. The Arabians still esteem it for its flesh, its teeth, and skin, and name it *Naqua el baher*. There can be little doubt that the strange *fish* described by Forskal under the name of *Naqua*, was in truth this very dugong.—(*Descrip. Animalium, &c. quæ in itinere orientali observavit*). Ruppel observed it swimming among the coral banks which border the Dalac Isles on the coast of Abyssinia, between the 15° and 16° South Lat. The fishermen call it *Dauila*. They harpooned a female ten feet long, which our traveller dissected and described. He was further informed by the Arabs, that these Dugongs live in pairs or small families; that their voices are very feeble; that they feed on algæ; and that, in the months of February and March, bloody combats take place among the males. The females produce in November and December. The former sex attains to the length of eighteen feet,—the latter never equals that extent. We may add that M. Sommering (merely, however, from a comparison of the writings of Home with those of Ruppel), doubts the fact that the supposed species of the Red Sea is specifically distinct from that of the Indian Archipelago.

The *Stellers* are most voracious creatures, and feed with their heads under water, quite inattentive to boats or whatever else may be passing around them. They swim gently one after another, sometimes with a great portion of the back out of the water, and every now and then they elevate their muzzles for the sake of respiration, making a noise like the snorting of a troop of horses. They were captured at Behring's Island by a great hook fastened to a long rope. This was taken into a boat, which was rowed amidst the herd. When struck into the animal, the rope was conveyed on shore, where about thirty people took hold, and drew it on shore with great difficulty. The poor creatures made the strongest resistance, assisted by their faithful and attached companions, and they clung to the rocks with the greatest pertinacity.[1]

DIVISION II.—ORDINARY CETACEA.

In passing from the herbivorous to the ordinary Cetacea, we may remark, that the former take the precedence in our systematic works, not from their superior importance but merely because they approximate more closely to those Mammalia which dwell upon the surface of the earth, and thus link more continuously with our preceding orders. This remark applies with equal force to the sequence in which the more pisciform Cete are discussed. We are in the habit of commencing not with those which are the most imposing of the Order, and the most important in an economical or national point of view, but with those which approach the nearest to the division we have left; and this mode of progression, it must be admitted, possesses an interest peculiarly its own. We begin, accordingly, with the lower and more insignificant links of the scale, and gradually ascend till we reach the great monarch of the deep, which, as to dimensions at least, is the great monarch also of creation.

SUBDIVISION I.—DELPHINIÆ. Head of ordinary proportion, with numerous teeth. Blow-hole single.

A. those which have a dorsal fin.

This subdivision comprehends a very great number of species and even genera, which it has been found necessary to distinguish from each other. Baron Cuvier threw out the idea of employing the facial line in their arrangement, and this view has been further extended by M. de Blainville. We regard the suggestion as valuable and convenient, and shall therefore adopt it. Five distinctive variations of the line alluded to have already been selected as useful in the classification of these lesser Cete. These we have sketched on Plate XVI., at figures 6, 7, 8, 9, 10; to which we shall have occasion subsequently to refer.

GENUS (*a.*)[2] INIA, D'Orbigny. The beak is long like that of the dolphin, but cylindrical, and bristled with strong hairs; it has many teeth, incisives anteriorly, molars posteriorly. The temporal fossa and crest are also peculiar.

There is but one known species in the genus, the *I. Boliviensis*, D'Orbigny and Fred. Cuv. (See Plate XVI., fig. 11.) It is to the first named of these eminent naturalists that we are indebted for our acquaintance with this curious animal (very properly made by him to constitute a new genus), which establishes a link between the *Stellerus* and the *Soosoo*. This last frequents the Ganges, an hundred miles from the ocean; but the *I. Boliviensis* is met with thousands of miles from the sea, and is an inhabitant solely of rivers and fresh-water lakes. It is the only species of the whale tribe characterized by such peculiar localities. M. D'Orbigny found it in the early tributaries of the Amazons, 2100 miles from the ocean, at the foot of the Eastern Cordilleras, and was not a little astonished at his discovery. We must condense his description into the following formulary: Snout resembling a prolonged and very slender beak, almost cylindrical, obtuse at the point, and bristled with long strong coarse hair; the commissure of the lips reaching very far back, so as to be over the pectorals; pectorals very far forward, broad, long, and obtuse; dorsal-fin very low, two-thirds down the back; tail large, length 12 or 14 feet. Colour usually pale-blue above, passing into a rosy hue beneath; the tail and fins are bluish. Teeth $\frac{34 - 34}{33 - 33}$, $= 134$; many of them marked with deep and interrupted grooves. The auditory opening is larger than in most of its congeners; and we are not aware that the bristles on the beak have been seen in any of the other Cetacea. The appearance of the teeth is singular; they resemble incisors anteriorly, and posteriorly have an irregular mammary shape. This peculiarity, illustrated on Plate XVI., figure 5, somewhat approximates the *Boliviensis* to the herbivorous Cete, which it also resembles in its brilliant colouring.

This Inia comes more frequently to the surface of the water than its marine congeners, and appears less remarkable for agility and power. It habitually unites in little troops of three or four individuals, which are observed to raise their snouts from the water whilst devouring their prey, which appears to consist entirely of fish. In Bolivia they are hunted for their oil.[3]

GENUS (*b.*) SOOSOO, Lesson. The bony frame-work, more than any other part, forms the peculiarity of this genus, especially the long symphysis, and the great maxillary crests which rise above the walls of the spiracles. Besides, there is no furrow between the head and beak; the latter is very long, and slender, compressed at the sides, and expanded towards the extremity, so that it is broader at this part than in the middle.

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[1] See Steller's valuable paper *De Bestiis Mar.* in *Nov. Comment. Acad. Petrop.*, t. ii. p. 294.

[2] The Arabic figures which we have made to precede the generic names of this extensive subdivision relate to the abstract exhibited at page 229, and which we hope will render our arrangement more perspicuous.

[3] See *Nouv. Ann. du Mus.* t. iii.

S. Gangeticus, Less.; *Delphinus Gangeticus*, Lebeck, Roxburgh;[1] *Platanista Gangeticus*, Fr. Cuv. (See Plate XVI., figure 13.) Of all the beaked dolphins, says the Baron Cuvier, the most extraordinary, and that perhaps which most merits being formed into a distinct genus, is the *Soosoo* of the Ganges. Lesson accordingly formed it into a genus distinguished by the name under which the only established species is known to the natives of Bengal. Cuvier thinks it is probably the *Platanista* of Pliny. The osteology of the cranium, he states, approximates it to the sperm whales.

The length is about twelve feet; the head is obtuse, suddenly tapering to a long and slender, but very strong beak; the jaws are nearly equal, amounting to about one-sixth of the length of the whole animal. The pectorals are of an oblique fan-shape; there is no distinct dorsal fin, but an angular projection nearer the tail than the snout. The colour is a shining pearly white. Teeth $\frac{30-30}{30-30}, = 120$. Spiracle linear, of the shape of an *ſ*, running backwards. Vertebræ, cervical 7, dorsal 11 or 12, lumbar 28. We may add that the form of the spiracle is unlike that of most of the lesser Cete, and corresponds with that of the Cachalot, or sperm whale. The tail is curiously festooned, and the pectoral fin scalloped. The eyes are stated to be exceedingly minute, only about a line in diameter, and of a bright shining black colour.

The Soosoos, says Dr Roxburgh, are found in great numbers in the Ganges, even so far up as it is navigable, but seem to delight most in the slow moving labyrinth of rivers and creeks, which intersect the Delta of that river, to the south and east of Calcutta. When in pursuit of the fish on which it feeds, it moves with great activity and uncommon swiftness, but at all other times, so far as noticed by the last named naturalist, its motions are slow and heavy; and it often rises to the surface to breathe. Between the skin and flesh is a coat of pale-coloured fat, more or less thick, on which the Hindoos set a high value, as a remedy of great efficacy in external pains. The flesh resembles lean beef, but is never eaten by the natives. Though this is the only known living species, it may be mentioned that Baron Cuvier has established the existence of several fossil kinds.

We must now take our leave of those smaller Cetacea which frequent only the shallow bays of the sea coast, browsing upon marine vegetation, or inhabiting "the rivers of water," to follow the far more numerous groups which revel throughout the vast depths of the unbounded ocean. The haunts of many of these are of course less known; and the facilities of capturing, and more especially of scientifically examining them, are greatly diminished. No wonder, then, need be excited by the avowal that a deep veil of obscurity lies over the history of the great majority, which all the bygone assiduity that has been exercised has as yet but partially removed. Our best endeavours will here be used to present the reader with whatever authentic information the accumulated efforts of naturalists have hitherto supplied, although, in the present embroiled condition of the subject, we cannot ensure ourselves against the chance of error.

Genus (*c.*) Delphinorhyncus. Snout prolonged, with a beak not distinguishable from the forehead by a furrow, or in other words, with the facial line almost continuous to the extremity of the muzzle. (See Plate XVI., figure 7.) A dorsal fin.

It was M. De Blainville who introduced this generic division, and it has been adopted by Desmarest, the Baron Cuvier and his brother, M. Lesson, and others. Though the distinguishing characters are sufficiently precise, yet, from the recent introduction of the generic term, and still more from our want of knowledge of the species, most of which have been only partially described, there is much doubt as to the ascertained number comprehended in the genus. Desmarest enumerated four, Lesson five, and M. F. Cuvier in his *Cetacés* only three. One of the last named author's species (*D. micropterus*) we reject, because it had many years before his proposed arrangement, been elsewhere and more accurately placed. His other two correspond with two of M. Lesson's. But of the five described by M. L., we must reject his *Malayanus*, because it possesses the characters of the genus Delphinus. Another of these species (*D. maculatus*) must be received with hesitation, because it has never been captured, nor of course examined, though observed with care from a vessel's deck. To these four of M. Lesson we shall now direct our attention.

D. Bredanensis, Less.; *D. rostratus*, Cuv.,[2] Fr. Cuv. (in his Mem.);[3] *Delphinus rostratus*, Cuv.,[4] Desm.;[5] *D. à bec mince*, Desm., Fr. Cuv., Less. (See Plate XVI., figure 14.) In this species, as in the rest of the genus, the profile of the cranium loses itself insensibly in that of the beak. Length of the only specimen examined eight feet; dorsal fin rising nearly from the middle of the back; pectorals falciform; colour sooty-black above, rose-colour beneath. Teeth $\frac{21-21}{21-21}; = 84$. As frequently happens, the osteology, and especially that of the cranium, has been known longer, and more accurately, than any other part of the animal. The city of Brest supplied some crania for the investigation of Baron Cuvier, as did M. Van Breda, Professor of Natural History at Gand; and accurate drawings of an individual thrown ashore on the coast of France, reached Paris, and removed all doubts as to its peculiar features. The colouring, we may remark, is singularly beautiful. All the upper parts are of a deep sooty-black, and the lower of a rich rosy hue. These portions are not separated by a distinct and uniform line; on the contrary, their junction is quite irregular, and many small black patches are figured upon the fairer colour. This species would appear to be an inhabitant of the Atlantic; but we believe it has not been seen alive, and we are not aware that any more information has been obtained regarding it than what has now been stated.

D. coronatus, Desm., Cuv.,[6] Less., Fr. Cuv.; *Delphinus coronatus*, Frémenville. Head small; forehead convex, obtuse; jaws prolonged into a pointed beak, the lower the largest. Teeth $\frac{15-15}{22-22}$, pointed and acute; general form elongated; dorsal fin nearer the tail than the head; pectorals of moderate size; tail crescent-shaped; length from 30 to 36 feet; colour a uniform black, but having two yellow concentric circles placed on the forehead,—the larger three inches diameter, the smaller about two. Hence its specific appellation. On the authority of the preceding noted names, we rank this very interesting species as a Delphinorhyncus, though we cannot dismiss all doubts upon the subject. Our knowledge of its existence rests solely, strange to say, upon the authority of M. De Frémenville, a distinguished naturalist, and officer of marine, who commanded an expedition towards the North Pole in 1806, chiefly for the purpose of geographical investigation. All subsequent accounts have been derived from that author.[7] He remarks that the only kind of whale he can describe with confidence, is a species which appears to have been previously unobserved. After supplying the description of its external characters, he adds, " the *coronatus* is common in the Polar Seas. I first met with it about 74° N., but it is chiefly between 77° and 80°, among the ice-islands near Spitzbergen, that it is found in numerous troops. Frequently during calms we were quite surrounded by it. These animals were so little shy that the water which they spouted fell on the deck. Their spouting was attended by considerable noise, and was effected with such force, that the water was immediately dispersed, and had the appearance only of a slight vapour; the jet itself did not rise above six feet."

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[1] *Asiatic Researches*, vol. vii. 170.

[2] *Règ. An.* t. i. 289.

[3] We may note that in his *Cetacés* M. F. Cuvier has put this species back among the true dolphins,—we think erroneously,—as it had long been regarded as the type of the Delphinorhynci.

[4] *Ann. du Mus.* t. xix.

[5] No. 764. Description imperfect.

[6] *Reg. An.* 289.

[7] See *Mem. de la Soc. Philom.* for 1818, and Fr. Cuvier's *Cetacés*.

D. Geoffroyi ?, Desm., Less.; *Delphinus Geoffroyi*, Blainv.; *D. frontalis*, Cuv. and F. Cuv. The fall of the frontal convexity is rapid; the beak marked and compressed; the specimen in Paris measured seven feet; the beak about ten inches; the horns of the spiracle are pointed backwards; the dorsal-fin very low; the pectorals well developed, and inserted low in the side. The specimen is painted grey on the back, white on the belly and round the eyes, the fins rosy-white. These are thought to be the colours of the living animal. The only specimen now known was brought from the Museum of Natural History of Lisbon to Paris by M. Geoffroy, in 1810. The colours indicated cannot with certainty be depended upon. It is supposed to have been brought from the Brazils.

D. maculatus ?, Less.; *Delphinus maculatus*, Fr. Cuv. Head slender, terminated by a long beak; body elongated, reaching to about six feet; dorsal fin placed in the middle; tail large. The colour in the water appeared a bright green, but out of it, the tint of the back was azure, of the belly grey, dappled with round spots bordered with red; the edges of the jaws, and especially of the upper one, were pure white. This species was seen, but not captured, in 18° S. and 137° W.

In advancing from the recently established genus DELPHINORHYNCUS to that which is the oldest, perhaps, of any, viz. DELPHINUS, we wish we could inform our readers that we leave a region of hesitation and doubt for one of certainty and precision. This, however, is not the case; and the cause is evidently to be found in the many and great difficulties by which the subject is encompassed. These animals, residing in haunts so different from those frequented by man, are but rarely encountered, and when met with, are seen under circumstances in which examination is difficult, and capture almost impracticable; for they pass us by, and vanish, almost like the vessel's track upon the rolling waves. It is only then, by some very fortuitous circumstance, or by great and peculiar labour, that when seen they are secured,—and the chances are still more remote of their being rendered available to the advancement of science. But instead of dilating upon these difficulties, we shall simply state a striking proof of their magnitude. In 1822 Desmarest enumerated sixty-two species as belonging to the whale order; but he considered no fewer than twenty-nine of them doubtful and not established; and Lesson, in 1828, out of eighty-four species which he classified, could vouch for the accuracy and existence of not more than fifty. With regard, again, to the genus now before us, M. Fred. Cuvier, in his history of the Cetacea, published in 1836, while he regards sixteen species of proper dolphins as pretty well ascertained, describes seventeen, the existence of which is still doubtful. Linnæus had three species in his genus Delphinus; the number has now been multiplied more than tenfold. The greatest discrimination, however, is required; for, while some are to be regarded as unquestionably established, and others rest upon a high probability, or it may be, on a very low one, yet even the slightest notice may be valuable, and should not be lost to science. On the other hand, there are instances in which species which were at first erroneously admitted, have long passed current as established in the records of Cetology, and some of these can scarcely be excluded without a reason being assigned for doing so. As the authors we have named indicated the different degrees of probability on which the species rest, we shall follow their example, and shall distinguish, 1st, Those which appear to be established; 2dly, Those which are probable, though not free from doubt; and, 3dly, Those which are not only doubtful, but highly questionable.

GENUS (*d.*) DELPHINUS, Cuv., Desm., Blain., Less., Fr. Cuv., Gray. Forehead convex; snout in the form of a beak, and distinguished from the forehead by a marked furrow. (See Plate XVI., figure 8.)

D. Delphis, Linn., Bon., Lacépède, Desm., Cuv., &c., popularly, *Oie de Mer*, or Dolphin. (See Plate XVI., fig. 12.) This animal is perhaps more generally known through the fictions of ancient poetry, than by its soberer name of *goose of the sea.* It is universally considered as the dolphin of antiquity, or at least as the only actual origin of that fabled being, though assuredly unendowed with those extraordinary attributes and charms with which it has been so fancifully clothed. It is the *Hieros Ichthys*, or sacred fish of the heroic Greeks, and was awarded divine honours by that imaginative people. It was more particularly sacred to their god Apollo; the reason assigned for which is this,—that when Apollo appeared to the Cretans, and obliged them to settle on the coast of Delphis, where he founded that oracle so famous throughout antiquity, he did so under the form of a dolphin. Apollo was thus, according to Visconti, adored not only in connection with the Delphine province, but with the Delphinus fish. He was worshipped at Delphi, with dolphins for his symbols. The ancients respected the dolphin as a benefactor of mankind; they cherished the tale of Phalanthus, the founder of Tarentum, being carried ashore by a dolphin when wrecked on the coast of Italy; and fondly believed in the story of the musician Arion, who, when about to be thrown overboard by the sailors that they might appropriate his wealth, begged that he might be permitted to play some melodious tune, and then throwing himself into the sea, was received by one of the many dolphins which had been attracted by his music, and carried on its back in safety to Tænarus. It is also recorded, that the shield of Ulysses bore an image of the dolphin, and it is certainly found on very ancient coins and medals. It early appeared on the shield of some of the princes of France; and gave a name to a fair province of that empire, and hence a title to the heir-apparent of the crown.

Scarcely less fabulous are those other narratives which have been transmitted on the testimony of early naturalists. They tell us that the dolphin made itself familiar with man, and conceived a warm attachment for him. Pliny narrates that in Barbara, near the town of Hippo, a dolphin used to frequent the shore, and accept of food from any hand which supplied it; it would mix among those who were bathing, would allow them to mount its back, would consign itself with docility to their direction, and obey them with as much celerity as precision.[1] Still more extraordinary is that other tale narrated to illustrate the assertion that the dolphin is more partial to children than to adults. Thus, according to Pliny, it was recorded in several chronicles that a dolphin which had penetrated the Lake of Lucrinus, in Campania, every day received bread from the hand of a child, answered to his call, and transported him to the other side of the lake, on its back, to school. This intimacy continued for several years, when the boy dying, the affectionate dolphin, overwhelmed with grief, sunk under its bereavement. But with such stories as these, which might easily be multiplied from Herodotus, Plutarch, and other ancients, we shall not further tax our readers.

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[1] Lib. ix. c. 48.

The common dolphin (*D. delphis*) is usually five or six feet long, but sometimes measures eight or nine. For its general appearance we refer to our representation in lieu of many details. (See Plate XVI., figure 12.) The tints, though not gay, are attractive. It is black on the back, and white underneath, with a peculiar glistening when in, or newly taken from, the water. It may be well, however, to remark, that "the dolphin, with its many dying hues," as mentioned in many books, and sung by modern poets, is not this creature, but another of a different nature, belonging even to a separate great division of the animal kingdom. It is a true fish, the beautifully coloured *Coryphæna Hippuris*, the Dorado of the Portuguese, and it would be well if its popular name (involving as it does a double application) were entirely dropped. The eyes of the common dolphin are small and supplied with eyelids: the pupil is in the form of a heart. Mr Rapp has minutely described the lachrymal gland, the peculiarities of which Mr Hunter, indeed, had previously pointed out. There is no olfactory nerve, nor ethmoidal foramina. The meatus auditorius is apparent, though very small. The jaws are equal; teeth $\frac{47-47}{47-47}$, = 188, pointed, slender, and somewhat curved, at equal distances from each other, and locking together when the mouth is closed. There are seven cervical, twelve dorsal, and fifty-two other vertebræ. Finally, the brain of the dolphin is very large, and developed to an extent which is quite extraordinary among the lower animals. Its weight, in relation to that of the whole body, has been stated as one to twenty-five, which is the same as that in man. The average of four accounts given in Cuvier's comparative anatomy is one-fiftieth of the whole; and Tiedemann, the highest modern authority in this department, remarks, "that the brain of the dolphin, next to that of the orang-outang, approaches nearest, in respect of size, to the human brain." This would lead to the supposition that its intelligence and mental capacity are considerable, and any indications which have been noticed are favourable to such opinion.

Few if any of the order appear to be more voracious than the dolphins. They live upon medusæ and fishes, especially upon flat fish, and cod, mullets, pilchards, and herrings. It used to be held that the common dolphin was an inhabitant of every sea throughout the world. This appeared the more credible, since the strength of the animal, and the velocity of its swimming, exceeding that of a ship in full sail, would readily account for its appearance in all seas, and even at the opposite poles.[1] A very different opinion, however, is now gaining ground, confirmatory of a sentiment of Buffon's in relation to land animals, more than once alluded to in the preceding portion of the present treatise, viz. that every distinct species has a characteristic and, with few exceptions, circumscribed locality. It is more difficult, of course, to ascertain the truth of this proposition, as it regards the inhabitants of the water, although many facts would seem to establish its truth with regard to the cetaceous tribes. The species now under review frequents the European seas, the Atlantic, and the Mediterranean; and other species of the genus occur in the seas of Africa, Asia, and America. They navigate the waters of the ocean in more or less numerous troops, and their strange gambols and rapid natation, which are daily observed by voyagers (with sometimes little else within their range of vision), has long made them famous. The common dolphin is peculiarly signalized by these qualities, which, however, it enjoys only in common with the majority of its congeners. To swim with the rapidity of an arrow, to shoot ahead of vessels which are scudding before the breeze, to spring out of the water and over the waves, are qualifications possessed alike by all the smaller Cetacea which live in the ocean.

The one we shall next allude to is almost the most perplexed of the genus. It is the

D. Tursio, Fab. 31, Bon., Desm. 761, Cuv., Less.; *D. Nesnarnak* of the Greenlanders, Fab., Bon., Lacép., Fr. Cuv.; *D. Oudre*, Belon, &c.; *Grand Souffluer* and *Great Dolphin* of the French; *Capidoglio* of the Italians, and Risso; *Bottle-nosed Whale*, Hunter, Plate 18, which he confounded with *D. Delphis*. *D. Orca?* Linn., Desm. 765. Head and beak of the genus; the lower jaw somewhat longer, and having a slight bend upwards; dorsal near the middle; pectorals oblong, pointed. Length stated from ten to twenty-four feet. Colour black above, whitish beneath, merging into each other on the sides. Vertebræ (six), seven, seventeen, twenty-seven = sixty (Hunter). Teeth $\frac{23-23}{21-21}$; of one form, straight, cylindrical, and blunt at the summit. Inhabits Northern Seas, Atlantic, and Mediterranean. The account of the "History of the natural history" of this species, would lead us into a very intricate and not very profitable discussion.

D. Nesarnak?[2] Cuv.[3] Desm. 762. The principal alleged difference dwelt upon by these eminent men is the number and arrangement of the teeth. We are disposed wholly to reject this as a distinct species.

D. Boryi, Desm. 757, Desmoulins,[4] Less., Fr. Cuv. Beak longish, much compressed, and very broad near the head, which is rather elevated; dorsal in the centre; length about eight feet. Colour mouse-grey above, bright grey beneath, and there striped with light blue. Known at once by a band of ivory-white on the sides of the head, very distinct from the grey underneath it.

Twice seen, near Madagascar, by Col. Bory de St Vincent, a learned and zealous naturalist, who communicated the particulars to Desmarest. On being captured the blue stripes underneath speedily disappeared.

D. frontalis, Dussumier, Cuv.;[5] *D. dubius*, Fr. Cuv. Head and beak of the genus; length of the specimen examined four and a half feet; dorsal somewhat behind the middle; pectorals attached one-fourth of the distance of the whole length from the anterior extremity, and one-sixth of the whole length, pointed. All the upper part of the body, sides, and tail a deep black; belly white, with a leaden-coloured streak running from the angle of the mouth to the base of the pectorals, which are quite black. Teeth about $\frac{36-36}{36-36} = 144$.

This species was captured by M. Dussumier near the Cape-de-Verd Islands. M. F. Cuvier has identified it in his Mammifères, and Cetacés with the *Dubius*; but so did not the Baron, nor do we think sufficient reason has been assigned for the step.

D. Pernettyi, Pernetty,[6] Desm. No. 756, F. Cuv. Re-

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[1] Quoy les a vus souvent, dans le voyage de l'Uranie, précéder la frégate filant de neuf à onze nœuds par heure, comme on voit les chiens danois précéder les équipages dans les rues et les promenades publiques. On voit ainsi deux, trois, ou quatre Dauphins, quelquefois un tout seul s'exercer à lutter de vitesse, et par leurs zig-zags entrecroisés sous la pointe du beau-pré (et cela pendant des journées antiéres), faire quatre ou cinq fois plus de route que le vaisseau qui file de quatre à cinq lieues par heure."—*Diction. Classique d'Hist. Nat.*, t. v. p. 350.

[2] Wherever the mark of interrogation (?) follows the name of a species, we mean it to be understood that the existence of that species is extremely doubtful.

[3] *Ann. du Mus.* t. xix. 9.

[4] *Dic. Classique d'Hist. Nat.*

[5] *Règne Animal*, 288.

[6] *Voy. aux Malouines.*

Cetacea.

garded as a variety of the *Delphis* by Bonnaterre and Baron Cuvier. Head and beak of the genus; lower jaw somewhat longer than the upper; dorsal pointed, and placed behind the middle; colour black above, pearly grey below, and mottled with dark spots; teeth acute, and somewhat like those of the pike.

The vessel of Bougainville, in which Pernetty sailed, when near the Cape-de-Verd Islands was surrounded by about 100 of these dolphins, which approached very near it. They appeared, says Pernetty, to have come only for the purpose of diverting us; they made extraordinary leaps out of the water, some of them vaulting four feet high, and turning over two or three times in the air. The one taken weighed 100 pounds. To the common characters, which we have specified, Pernetty adds another, which we believe may be referred to many of the order, viz. that it exhaled an odour which was so strong and penetrating, that whatever substance was once impregnated with it, retained it for many days, in spite of all that could be done to overcome it.

D. Malayanus, Cuv.,[1] F. Cuv.; *Delphinorhyncus malayanus*, Lesson and Garnot. Head large, forehead convex, falling suddenly, and presenting a marked furrow at the origin of the beak, which is prolonged and thin; upper jaw somewhat larger than the lower; teeth numerous; length of the specimen taken six feet; dorsal in the middle; of a uniform ash-colour. This species was taken in the middle of the Indian Seas. In common with Mr F. Cuvier, we do not understand how M. Lesson should have ranked it with the *Delphinorhynci*. Baron Cuvier suspects it may be the same with the following species.

D. plumbeus, Dussumier, F. Cuv. General proportions of the genus; length eight feet; the dorsal starts from about a third of the anterior extremity; colour uniform leaden-grey, with the exception of the extremity and lower portion of the beak, which are whitish; teeth $\frac{36-36}{32-32}$, = 136. This species was detected off the Malabar coast by M. Dussumier, who states that they frequent the shores, and pursue the shoals of pilchards. Their motions are less rapid than those of their congeners, which are found in the midst of the ocean. The natives capture them in nets, but with much difficulty, because they seem to suspect their intentions, and very cautiously avoid the snare. The noise of a musket makes them flee in all directions; and after having sunk beneath, they take a direction different from that which their plunge indicated. These circumstances manifest something of that mental capacity with which the dolphin is generally supposed to be endowed.

D. frænatus, Duss., F. Cuv. Four and a half feet long; dorsal in the middle,—its length one-fifth of the whole body,—its form triangular and pointed; pectorals long and slender; colour black on the back, pale on the flanks, white on the belly, as is the lower half of the tail, the upper half being quite black; head black above, and of an ash tint on its sides, with a streak of a deeper hue, forming on the cheek a kind of bridle, extending from the commissure of the lips, under the eyes; teeth numerous, but their precise amount not ascertained. Taken by Dussumier to the south of the Cape-de-Verd Islands.

D. velox, Duss., Cuv.,[2] F. Cuv.;[3] *D. leger*, F. Cuv.;[4] *the swift dolphin*. Head and beak of the genus; beak long; length five feet; all the fins long and broad; dorsal over the middle; colour wholly black; teeth $\frac{41-41}{41-41}$, = 164. Dussumier met this species between Ceylon and the Equator. When one was harpooned the whole group instantly disappeared. They swam with extraordinary rapidity; hence their name.

D. longirostris, Duss., Cuv.[5] Our only information regarding this species is that in the Règne Animal taken from Dussumier's manuscripts. M. Dussumier captured it off the coast of Malabar. The number of its teeth exceeds that of most of the genus; the formulary is $\frac{60-60}{60-60}$, = 240.

D. superciliosus, Less. and Garnot, F. Cuv. Total length between four and five feet; dorsal somewhat beyond the middle; upper part of the body of a brilliant bluish-black colour, sides and under parts of a silvery whiteness; pectorals brown, on a white ground; but what especially characterizes this dolphin is a large white spot over the eye in front; another long white mark occurs on the sides of the body near the tail. Teeth, $\frac{30-30}{29-29}$; = 118. It was captured by Garnot off Van Diemen's Land.

D. Novæ Zelandiæ, Quoy and Gaimard, F. Cuv. Head and beak of the genus; lower jaw somewhat longer than the upper; dorsal large, triangular, rounded at top; pectorals of average size, falciform; tail small. Length between five and six feet. Colour dark brown above, lower part of beak and body dull white; a large yellow stripe commences at the eye, and terminates, growing narrower on the flanks, beneath the dorsal; tail of a slate colour, pale underneath; pectorals of the colour of white-lead, also the dorsal, both tipt all round with black; there is a black line over the snout, becoming larger towards the eye, which it surrounds; this line is accompanied on either side with a white line. Teeth, $\frac{43-43}{47-47}$; = 180.

D. cœruleo-albus, Meyen, F. Cuv. Facial line of the genus; snout more curved and compressed than in the common dolphin; pectorals more pointed; colour above, a deep steel-blue, as are the pectorals; a marking begins large at the dorsal, descends towards the commissure of the lips, and comes to a point half way between them; another commences at the pectorals and terminates in the black marking which surrounds the eye; this latter extends posteriorly, widening as far as the vent; the rest of the body is of a pure and brilliant white. M. Meyen observed this species on the east coast of South America. The specimen he examined was taken at the mouth of the Plata.[6]

D. Capensis, Gray.[7] The entire length of this animal is 81 inches; his widest girth 42. The back, lips, and fins are black; the belly white. Teeth about $\frac{50}{50}$, = 100. From the tip of the nose to the angle of the mouth he measures 13 inches; to the angle of the forehead 7; to the blower 7½; to the dorsal fin 38; to the pectoral 21. The length of the dorsal fin is 12; along the curve 12, and its perpendicular height 10; the length of the pectoral along the curve 13; the breadth of its base 5. The breadth of the tail is 18; and the length of each of its lobes along the curve 13 inches. This dolphin, says Mr Gray, is at once distinguished by the shortness of its beak. Its habitat is the Cape of Good Hope, whence it was sent to the Museum of the Royal College of Surgeons, London, by Captain Heaviside. Considerable discrepancy exists between the description and the plate by which it is accompanied.

D. dubius?, Cuv.,[8] Desm., No. 760. Less., F. Cuv. Cranium shaped like that of *D. delphis*, though somewhat smaller; beak more slender and pointed; upper jaw slightly conical, but not bent upwards; altogether smaller than the common dolphin. Teeth $\frac{37-37}{37-37}$; = 148. This species (still entitled to the name of *dubius*) was proposed by Cuvier from the examination of specimens, chiefly of crania, transmitted from the western coast of France.

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[1] *Règne Animal*, 288.

[2] *Règne Animal*, 288.

[3] *Cet.* 154.

[4] *Mammifères.*

[5] *Règne Animal*, 288.

[6] *Nov. Act. Cur. Nat.*

[7] *Spic. Zool.* part i. plate ii. fig. 1.

[8] *Mem. du Mus.* t. xix.; *Règne Animal*, 288.

D. niger?, Abel Rémusat., Lacép.,[1] Desm., No. 763. F. Cuv. Beak flat and very long; dorsal very small, and nearer the tail than the pectorals; colour mostly black, but white on the commissures of the lips, and margin of the pectorals, and part of the tail. Teeth more than 24 in each jaw. Introduced by Lacépède, on the faith of Chinese paintings procured in China by M. A. Rémusat. This species requires confirmation.

D. lunatus, Less., F. Cuv.; *Funenas* of the Chilians. Massive in its form; about three feet in length; beak slender; dorsal round at top; colour, a clear fawn shade above, gradually passing into white beneath; a brown and accurately defined cross is seen on the back on a line with the pectorals, and anterior to the dorsal. This small dolphin, according to Lesson, destroys an immense number of fish; and every morning at sunrise he noticed numerous troops of them, unceasingly diving in search of prey. By ten o'clock in the morning, when they had well breakfasted, they devoted themselves to play, and seemed delighted while striving which should rise the highest. He adds, that he saw this species only in the Bay of Talcahuana, in the province of Concepcion, where, however, it is extremely common.

D. minimus, Less., F. Cuv. About two feet in length; colour generally brown, with a white spot on the snout,—the latter slender. This species was seen by Lesson near the Moluccas, where they existed in thousands, frequently following each other in a uniform course forming two lines, in which they were arranged checquer-wise.

D. cruciger? Quoy and Gaimard, Less., F. Cuv. The flank is white, with a black line nearly throughout its whole extent; the dorsal is acute; total length but a few feet. This species was seen (but not taken) between New Holland and Cape Horn. It is suspected by M. F. Cuvier to be the same as the *Ph. bivittatus.*

D. albigena? Quoy and Gaimard, Less., F. Cuv. Colour generally black, with a white band on each side of the head, extending from the eyes as far back on the flanks as the dorsal-fin, which was of small dimensions. Observed (but not captured) by Quoy and Gaimard in the Antarctic Seas, and often seen by M. Lesson in the neighbourhood of New Holland.

D. Bayeri? Risso, Less., F. Cuv. Head equal to one-third the size of the whole body; snout much prolonged, obtusely pointed, and but little elevated, of the same form as in the dolphin. The opening of the mouth very large; teeth $\frac{34-34}{34-34}$, = 136; pectorals very broad; dorsal small and triangular; length forty-two feet; colour dull blue above, and whitish below. This species is doubtful and requires renewed examination. It was first noticed by Bayer, who considered it a cachalot;[2] but Risso having procured a drawing of what he believed to be the same animal, stranded at Nice in 1726, described it anew, and gave it Bayer's name. The characters stated above are from Risso's description. Baron Cuvier and his brother, with their eye fixed on Bayer's description, lean to the opinion that it was a cachalot.

D. Canadensis? Desm., No. 767, Duhamel,[3] Blain., F. Cuv.; *Dauphin blanc*, Desm. Head round, forehead elevated; beak pointed, and clearly distinguished from the forehead; length of specimen referred to twelve feet; colour white. Duhamel's description of this more than doubtful species is derived from information received from Canada. Whilst Desmarest regards it as a Delphinus, Baron Cuvier is disposed to refer it to the *Delphinorhyncus Geoffroyi*, and F. Cuvier to identify it with the Beluga.

D. Chinensis? Osbeck;[4] *D. Sinensis*, Desm. No. 759, F. Cuv. In the words of Osbeck, "it was like the common dolphin, but wholly of a white shining colour." He only *saw* this animal in the China seas. Bonnaterre[5] considered it a variety of *D. delphis*, Desmarest as a distinct species, and Baron Cuvier was disposed to regard it as a *Delphinapterus.*[6]

D. Bertoni? Desm. 768, Duhamel, Blain., F. Cuv. Forehead prominent; beak long and thick; upper jaw longer than lower; teeth confined to the latter; pectorals high in the body; the dorsal very small. Introduced by Desmarest on the imperfect data supplied by Duhamel. Habitat unknown; existence very doubtful.

D. Kingii? Gray.[7] "When the cranium is compared with the Beluga, the beak is found shorter by a half, and narrower in the exposed part of the maxilla, which edges the point of the blowers; the cavity of the cranium more globular, and the blower more anterior; teeth $\frac{9 \text{ or } 10}{9}\ \frac{9 \text{ or } 10}{9}$ small conical and recurved." Obtained on the coast of New Holland, and sent by Captain King to the British Museum.

D. longirostris?[8] Gray.[9] The existence of this our final species, is founded upon a cranium only, in Brooke's Museum. The beak, says Mr Gray, is more slender and depressed than that of the *D. Delphis*; the palate-bone is more strongly keeled; and the elevated central process of the upper surface of the beak is broad and convex. The length of the head is 6 inches; the beak $11\frac{1}{2}$; breadth of the latter, at the base, 3 inches. Teeth 48 to 50 in each jaw.

The PORPOISES, to which we now proceed, in their habits and dispositions very closely resemble the dolphins; and it is for the convenience of classification only that distinction is desirable.

GENUS (*e.*) PHOCÆNA, Cuv., Less., Gray. Head and snout short and gibbous, no beak, the facial line descending in a uniform connexity to the end of the snout; numerous teeth in both jaws; a dorsal fin. (See Plate XVI., figure 9.)

P. communis, Cuv., Less., &c.; *Delphinus phocæna*, Linn., Bon., Lacép., Desm., &c. The *Porpoise*, or *Porpess* of the English; also *Pellock* or *Sea pork*. The *Suinhual*, and *Springwhal*, and *Tumbler* of the Danes. *Maris Sus.*—the *Marsouin* of the French. (See Plate XVI., fig. 15.)[10] Head typical of that of the genus; lower jaw somewhat more projecting than the upper; dorsal nearly in the middle of the body, triangular; pectorals oblong; length from four to five feet; colour bluish-black above, fading on the sides to white underneath; pectorals dark brown; vertebræ, according to Lesson, 7, 14, 45, = 66; Tyson numbers them 60. Ribs, according to Lacepede, Tyson, Cuvier, and Lesson, 13, according to Hunter and Jacob,[11] 16; teeth $\frac{24-24}{24-24}$, = 96. Tyson.

The porpoise is found in all the seas of Europe, and in the Atlantic. In some parts of North America its skin, like that of the Beluga, is tanned and dressed with considerable care. It is shaved down from its natural thickness till it becomes transparent, and is then manufactured into articles of wearing apparel; it also affords excellent coverings for carriages. In a report of a committee of the House of Commons on the public works of Ireland, it is stated "that porpoises abound in almost innumerable shoals on the western shores of Ireland." It is desirable that they should be converted to the same economic purposes as in Canada.

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[1] *Mem. du Mus.* iv.

[2] *Act. Cæs. Leop. Cur. Nat.*, t. iii.

[3] *Tr. des Pêches*, Part ii. Plate X. fig. 4.

[4] *Voy. a la Chine.*

[5] *Encyc. Meth.*

[6] *Oss. Foss.*, tom. v. 1st part, 289.

[7] *Phil. Mag.* 1827.

[8] This name is most unfortunately chosen, and should certainly be changed by the learned author. It cannot be synonymous with the *D. longirostris* of Dussumier and the Règne Animal (see our p. 176) which is quite entitled to maintain its appellation.

[9] *Spic. Zool.* part i. p. 1.

[10] We are indebted for this original and very correct representation to the late Dr Macgillivray.

[11] *Dublin Phil. Jour.*, vol. i.

P. Grampus;[1] *Delphinus grampus*, Desm. 774, Hunter; *D. Orca*, Fab., Linn., Bon., Lacép., Shaw; also the *D. Gladiator* of Bon. and Lacep.; the *Grampus* of the English; *Epaulard* of the French; especially the *Buttskoff* of northern nations; the *Killer* and *Thrasher* of the Americans; the *Sword-fish* of the Greenlander; *Epée de Mer* of Bon., &c.; conjectured to be the *Aries marinus* of the ancients; Cuv. Oss. Fossil, t. v. p. 282. Head and snout of the genus; upper jaw somewhat larger than the lower; lower rather broader than upper; body elongated; from twenty to thirty feet in length; dorsal-fin central and very large, —four feet high; pectorals also very large, broad, and oval; colour black above, and white beneath, with a well marked line of junction; a white mark over the eye, and a black streak running forwards from the tail into the white portion; teeth $\frac{11-11}{11-11}$, = 44. Inhabits high northern latitudes, descending frequently into the Atlantic and German Ocean, and frequenting the coasts and friths.[2]

The grampus has the character of being exceedingly voracious and warlike. It devours vast quantities of fishes of all sizes, especially the larger ones. When pressed with hunger it is said to throw itself on every thing it meets with, not sparing the smaller Cetacea. Hunter found a portion of a porpoise in one which he examined. It is also said to make war on seals, and that when it espies them on the ice, it endeavours to drive them into the sea, where they become an easy prey. This species is often seen in small herds of six or eight, apparently amusing themselves, and chasing each other; and it is alleged, that when thus assembled they frequently attack the great Greenland whale. During this unprovoked and outrageous onset they are said to resemble so many furious mastiffs fighting with a wild bull: some seizing the tail and endeavouring to impede its murderous blows, whilst others attack the head, lay hold of the lips, or tear away the tongue. They have thus received the appellation of *Balænarum tyrannus* from the accurate Fabricius; and hence too the popular names of *Thrasher* and *Killer*.[3] We apprehend, however, that these bloody fights, recorded with such minute accuracy in many works on the Cetacea, stand in need of confirmation.

P. ventricosus? Hunter's "second species of grampus." Plate 18. *Delphinus ventricosus*, Bon., Lacép., Blain., Desm., F. Cuv. Head and snout of the genus; jaws projecting equally; dorsal fin of moderate size, situate somewhat behind the middle; pectorals long, not remarkably broad. Hunter's specimen was eighteen feet long; colour black above and whitish underneath, gradually merging into each other; no white or black markings. Cuvier and others have conjoined this with the preceding, and perhaps correctly; but, from the differences above indicated, we prefer for the present to follow the respectable authorities just named, and to keep it distinct. Hunter's specimen was caught in the Thames.

P. griseus, Less., F. Cuv.; *Delphinus griseus*, Cuv.[4] Desm., No. 775; *Paimpol porpoise* of Less.; *D'Orbigny's porpoise* of F. Cuv. Head and snout of the genus, though prominent; dorsal very elevated and pointed; pectorals enormously developed; total length ten feet; upper parts of the body and fins of a deep bluish-black, fading as it descends the sides, and giving place beneath to a dull white; no mark over the eye; vertebræ 7, 12, 42, = 61; ribs 12; teeth $\frac{0-0}{4-4}$, truncated; has been frequently stranded on the west coast of France.

P. compressicauda, Less. and Garnot, F. Cuv. Head round and prominent, terminating in a short obtuse point; upper jaw projecting slightly beyond the lower; length eight feet; dorsal somewhat behind the middle, triangular; pectorals small, attached low, form rather straight, and terminating in a point; tail rather small; leaden colour above, and whitish beneath; teeth $\frac{22-22}{23-23}$, = 90; lining of the mouth black. Captured by the crew of the Coquille, in latitude 4° S., longitude 26° W.

P. truncatus, *Delphinus truncatus*, Montague,[5] F. Cuv. Length twelve feet, circumference eight; black above, a purplish tinge gradually becoming dusky on the flanks, and sullied white beneath; lower jaw somewhat larger than the upper; teeth $\frac{20-20}{23-23}$, = 86, placed close together, circular, perfectly flat; some of the teeth nearly double the size of others, with no spaces between them; they were much truncated, some obliquely, and some at right angles. This species was taken in July, five miles up the Dart. Dr Fleming identifies it with the Tursio of Fabricius. We think his opinion is erroneous.

P. Capensis, Duss., Cuv.,[6] F. Cuv.[7] Head and snout of the genus, though somewhat flat; length four feet; dorsal somewhat beyond the centre, more than half a foot high; pectorals six inches long, three broad, rounded at their extremity; colour all over black, with exception of a white spot on each side, somewhat behind the dorsal; teeth, according to Baron Cuvier, $\frac{28-28}{28-28}$, = 112; according to F. Cuvier, $\frac{26-26}{23-23}$, = 98; cylindrical, pointed, and not compressed as in the common porpoise. M. F. Cuvier names it *D. cephalorhyncus*,—apparently an unnecessary innovation.

P. Homeii, Gray.[8] Colour above pure black; sides of the head and body clouded black and white; belly white; on each side an indistinct band commences immediately under the dorsal fin, and descends obliquely and backwards, till it terminates on the under and posterior part of the body; a dusky-coloured circle also surrounds the eye; below, the anterior part of the jaw, and a space of nearly a foot and a half before the tail, dusky; snout thick, pointed, and not readily distinguished from the anterior part of the head; teeth $\frac{40-40}{36-36}$, = 152, slightly curved with the convexity outwards; pectorals long and pointed; dorsal fin placed behind the centre, large, high, and pointed, its hinder edge falciform; tail semilunar; usual length six feet. Mr Gray states that this species is often caught in Table Bay. Is it distinct from the preceding?

P. (Grampus) Heavisidii, Gray;[9] *Delphinus hastatus*,

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[1] Mr Gray has made this species the type of a new genus We do not, however, perceive the necessity or propriety of this.

[2] *Delphinus orca?*. Desmarest, besides the grampus above described, names a *D. Orca* (No. 765), noticed by Belon, and regarded by some as the *Orca* of the ancients. According to Cuvier, it has the facial line of a Delphinus. This opinion, however, rests upon a single sentence of Artedi, and its existence is very doubtful. It is said to inhabit the Mediterranean.

[3] The term *Thrasher* is also not unfrequently applied to a species of fox-shark (*Carcharias vulpes*), which, in common with the sword-fish, often attacks the whale.

[4] *Ann. du Mus.*, t. 9.

[5] *Wern. Mem.* vol. iii.

[6] *Règne Animal*, 289.

[7] *Mammifères.*

[8] *Zoological Journal*, iv.

[9] *Spic. Zool.* part i. plate ii.

Fr. Cuv.[1] Beak in a uniform line with the cranium, of moderate length, and large;[2] jaws equally projecting; "teeth 26 in upper and 25 in lower jaw;" dorsal fin not much elevated, placed somewhat beyond the middle; tail large; pectorals short. Length above five feet; colour generally black, head of a slate-colour, four markings underneath,—one in front of the pectorals, lozenge-shaped, two oval ones immediately behind them, and then a much larger one, covering a great part of the abdomen. The specimen which furnished Mr Gray with this description is in the Museum of the Royal College of Surgeons in London, and was sent thither by Captain Heaviside from the Cape, where M. Quoy again examined the species, in the cabinet of M. Verveaux, a naturalist settled in southern Africa. Their descriptions generally accord, though not in all particulars. Its habitat is presumed to be the neighbourhood of the Cape of Good Hope.

P. (*Grampus*) *obscurus*, Gray,[3] F. Cuv., Quoy.[4] Forehead and beak in a continuous line; teeth in the upper jaw 52, in lower 48, small and conical; dorsal fin two-fifths from the end of the snout. Length six feet. The back and upper part of the head black, the flanks and lower parts of the body white, with the exception of two bands running obliquely backwards,—one proceeding from the sides of the head, and terminating upon the pectorals, the other from under the dorsal, and terminating upon the belly. It is singular that these markings vary in different individuals, and are more apparent upon young than old animals. Mr Gray drew his description of this species also from a specimen in the Royal College of Surgeons, London. It had been sent from the Cape of Good Hope. M. Quoy, as in the former instance, found it in Mr Verveaux's museum.

P. Feres? Delphinus feres, Bon., Lacép., Desm., 766, F. Cuv. Head almost as high as long, much rounded on the summit, and suddenly sloping away anteriorly, where it terminates by a short round snout; jaws equal, covered with membranous lips; teeth $\frac{10-10}{10-10}$, $= 40$, some large, others small,—the former about an inch long, the projecting portion oval, round at the summit, and as it were divided into two lobes by a groove extending throughout their whole length,—the smaller teeth about half the size of the others. Length about fifteen feet; the whole body covered with a fine black skin.

This species rests solely on the authority of Bonnaterre, who received from the Abbe Turles of Frejus, a drawing of the skeleton, and a description of the external aspect. A shoal of about 100 were captured, after a hard struggle by the Provençals.

P. bivittatus? Lesson, F. Cuv. Snout short and conical; dorsal moderately high, black, and placed over the middle of the animal; pectorals thin, white, with the anterior edge black; tail brown, sloped in the middle; two feet and a half long; slender in its form; upper part of the body of a deep shining black; belly and lower jaw white; there is a large slash of satiny white running along each side of the body, but interrupted in the middle, opposite the dorsal, where the two portions of the band thus separated are enlarged. Suspected by F. Cuvier to be the same as *D. cruciger*. Seen by Lesson in great numbers off Cape Horn.

P. Agluk? Pallas, Chamisso, Less. Length thirteen feet; dorsal large; teeth small and numerous; colour black, with a white lateral streak passing from the commissure of the lips to below the pectorals, and another commencing before the dorsal, and proceeding obliquely underneath towards the origin of the tail.

P. intermedius? F. Cuv.; *Delphinus intermedius*, Gray.[5] This species is proposed by Mr Gray from an examination of a cranium in the British Museum, of the origin of which he knows nothing. He remarks that the cranium is very like that of *P. griseus*. The teeth, however, are $\frac{11-11}{10-10}$, $= 42$, whilst the last named species has seldom more than two or three in the lower jaw. This approximates the former to the *Orca* of Fabricius, from which, however, it differs in the small size of the temporal fossa, in the width of the temporal ridge, and the greater size of the space for the attachment of the occipital muscles.

GENUS (*f.*) GLOBICEPHALUS, Less. Characterized by having no visible snout; the head being nearly globular, and the mouth towards the under portion. (See Plate XVI., fig. 10.)

G. Deductor, Less.; *Delphinus globiceps*, Cuv.,[6] Desm. No. 777; *D. Melas*, Traill; *D. Deductor*, Scoresby; *Ca'ing whale* of Orkney; *Uyea whale*, Neill; *Grind whale* of Feroe; *Butshead* of the Danes. (See Plate XVI., fig. 16.) Head obtuse, upper part very much rounded; body thick; dorsal small; pectorals very long and narrow; colour generally black, with a white mark under the throat, extending along the belly; length about twenty-two feet; teeth $\frac{14-14}{14-14}$, $= 56$, conical, sharp, somewhat curved at their summit, and very apt to disappear; vertebræ 7, 11, 37, in all 55; ribs 11. Inhabits the northern shore of Europe, Iceland, Feroe, Shetland, Orkney, and the British and French coasts. Egede is perhaps the first author who makes mention of the *Deductor* under the name of *Butshead*; and he was soon followed by Duhamel, who gave a figure of one taken at Havre, under the name of "the porpoise with the round snout." In 1806 Dr Neill gave a more extended and interesting account of the species, under the name of *Uyea Sound* or *Ca'ing whale*, than any which had previously appeared;[7] and three years after Dr Traill published its first accurate description, under the name of *Delphinus melas*,[8] with a drawing, afterwards republished with additional details in Scoresby's work.[9] In 1812 an interesting memoir concerning the same animal appeared from the pen of Cuvier. He bestowed upon it the name of *Delphinus globiceps*.[10]

Of all the Cetacea this would appear to be the most sociable, often herding together in innumerable flocks. We may supply a few facts which establish this point. From an old history of the Feroe Islands, quoted by Mr Scoresby, it would appear that the inhabitants had long been in the habit of hunting and capturing them in great numbers. In the year 1664, on two excursions only, they killed about 1000; in the year 1748, 40 individuals of this species were seen in Tor Bay, and one seventeen feet long was captured; in 1799, about 200 ran ashore in Fetler, one of the Shetland Isles; and, in 1805, as mentioned by Dr Neill, in February 190, and in March 120 more, out of a herd of about 500, were forced ashore in Uyea Sound, in Unst; in 1806, 92 were stranded in Scalpa Bay, Orkney; in 1809 and 1810, 1100 of these animals approached the shore of Hvalfiord, Iceland, and were captured; in 1812, 70 were chased ashore near the village of Bloubalzbance, on the coast of Bretagne; and, in 1814, 150 were driven into Balta Sound, Shetland, and were there despatched. These are only a few of the instances in which, in modern times, an extensive capture of the *Deductor* has taken place; and we may add, that it is alleged to have been seen both off the American coast, and in high latitudes in the Pacific.

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[1] The multiplication of specific names is much to be lamented. We have here one of English origin, given by Mr Gray, and another from a French source, supplied apparently by M. F. Cuvier, but possibly by M. Quoy. The priority of publication ought to regulate our choice, and on this principle we have given due weight to the name of *Heavisidii*.

[2] We confess we have much difficulty in satisfactorily classifying these species so slightly sketched by Mr Gray: the descriptions would almost ally them with the Delphinorhynci.

[3] *Spic. Zool.* part i.

[4] F. Cuvier's *Cetacés*, p. 162.

[5] *Phil. Mag.* 1827, p. 357.

[6] *Ann. du Mus.*

[7] *Tour through Orkney and Shetland.*

[8] Nicolson's *Journal*, 1809.

[9] *Account of the Arctic Regions.*

[10] *Ann. du Mus.* t. ix.

It would be interesting to ascertain from what mental peculiarity it results that this animal is so frequently stranded, so easily hunted, and so readily made a prey. We have seen enough to demonstrate that they are most sociable in their habits; and we may now remark that they seem moreover to be endowed by an instinct very useful, doubtless, on the whole, whereby they are almost irresistibly induced to follow the guidance of the oldest and most experienced of their number. In the words of Dr Traill, they seem generally to follow one as a leader with blind confidence; and Dr Neill remarks, that the main body of the drove follows the leading whales as a flock of sheep follows the wedders. Hence the natives of Shetland well know that if they are able to guide the leaders, they are sure likewise of entangling multitudes of their followers. This trait is strikingly illustrated by a circumstance of which Dr Traill was a witness. "I once," says he, "was in a boat when an attempt was made to drive a shoal of them ashore; but when they had approached very near the land, the foremost turned round with a sudden leap, and the whole rushed past the boat." It is from this peculiarity in their mental constitution, that Dr Traill, it would appear, applied to them the appellation of *deductor*.

G. Rissoanus, Less. *Delphinus Rissoanus*, Cuv. Head large and round, upper jaw longer than the lower, dorsal high, in form of a scaline triangle, situated near the middle; pectorals large, broad and thick. Length nine or ten feet. Colour of the males a bluish-white, of the females a uniform brown, and both marked with irregular white lines, and brown spots. It inhabits the Mediterranean. (See Plate XVI., figure 8.)

G. leucocephalus? Less., Fr. Cuv. Head short, conical and truncated; dorsal very narrow, and acute at the summit. Length about six feet; body of a deep grey colour; head and neck of a dazzling whiteness. Lesson *saw* this species in the Archipelago of Pomotous, but did not capture any of the shoal.[1] He likewise mentions another observed in similar circumstances. It may be called the

G. fuscus? Less. Head completely truncated; dorsal high, falciform. Length ten or twelve feet. Colour a uniform brownish-black. The French naturalist was informed by the captain of an English whaler, that this was the *black fish* of the whalers, which, though very active, they were anxious to catch, because they found in its head a matter analogous to spermaceti.

We now proceed to a genus as yet but slightly known, though interesting and peculiar. It consists of those Cetacea which have two dorsal fins. This character, more curious than important, does probably not produce any marked difference between the habits of this little group and those of its congeners. It was established by M. Rafinesque Smaltz, and contains at present only two species.

B. Those which have two dorsal fins.

GENUS (*g.*) OXYPTERUS, Rafinesque Smaltz, Less., F. Cuv. Two dorsal fins.

O. Mongitori, Rafinesque Smaltz, F. Cuv. Named but not described by Smaltz in his *Precis de Sémiologie*, p. 13. He observed the animal in the Sicilian seas.

O. Rhinoceros; Delphinus Rhinoceros, Quoy and Gaimard, Less., F. Cuv. (See Plate XVI., figure 18.) A fin on the head inclined backwards, like that on the back; length ten or twelve feet; upper part of the body as far as the dorsal fin spotted with black and white.

"In 1819," say these interesting writers (Quoy and Gaimard), "in going from the Sandwich Islands to New South Wales, many dolphins, in troops, performed rapid evolutions about our vessel. Every one on board was surprised to perceive that they had a fin upon their head, bent backwards, the same as that on their backs. The size of this animal was about double the size of the common porpoise; and the upper part of its body to the dorsal fin was spotted black and white. We did our best to examine them all the time they accompanied us; but although they often passed the prow of the vessel, with the highest part of the back out of water, yet their head was so submerged, that neither M. Arago nor we could discover whether their snout was long or short; and their habits did not assist us on this point, because they never sprang above the wave, as is common with other species. From this very singular structure we have given them the name of *Rhinoceros*."[2] Though, from the circumstances detailed, our authors could not supply an accurate drawing, yet Messrs Quoy and Gaimard have furnished a sketch of the appearance of the species, which we copy from their atlas.

C. Those which have no dorsal fin.

GENUS (*h.*) BELUGA, Less. Gray. The osteology of the cranium, according to Baron Cuvier, supplies generic characters which distinguish this from the neighbouring genera. The form of the head is obtuse, conical, and rounded. The genus is moreover distinguished from the *Globicephalus* by having no dorsal fin; and from the *Delphinapterus* by having no prolonged snout-like flattened beak.

Beluga arctica, Less. *Delphinapterus beluga*, Lacép. *Beluga*, Shaw. *D. Leucas*, Linn. *D. albicans*, Fab. Bon. *White whale* of English whalers. (See Plate XVI., figure 17. Head obtuse and rounded; mouth small; teeth short and blunt $\frac{9-9}{9-9}$; no dorsal fin; pectorals large, thick, and oval; tail large and powerful. Total length from twelve to eighteen feet. Colour, of a light cream-colour. The shape of this animal is highly symmetrical, and at once suggests the idea of perfect adaptation to rapid progressive motion in water. Its head is small and somewhat lengthened, and over the forehead there is a thick cushion of fat; the body continues to swell as far as the pectoral fins, and from this point gradually diminishes to the setting on of the tail. The tail is powerful, bent under the body in swimming, and worked with such force that it impels the beluga forward, says Giesecké, with the velocity of an arrow. The colour is usually a uniform and beautiful cream-colour, whilst the younger ones are marked with brownish spots, and are somewhat of a blue or slaty colour. Dr Scoresby remarks, that he has seen some of a yellowish hue, approaching to orange; and this agrees with the statement of Fabricius, who says they are white, sometimes tinged with red. Many contradictory accounts are given of the number of teeth, in consequence, no doubt, of the fact, that in the beluga, as in most of the other whales, these parts have the greatest tendency to drop out as the animal becomes aged. Anderson states that it has no teeth in the upper jaw, and that this is the universal opinion of the Greenland fishers, while there are eight on each side in the lower;—thus, $\frac{0-0}{8-8}$. Dr Neill gives $\frac{9-9}{6-6}$, and Crantz $\frac{8-9}{6-6}$. Cuvier, however, states them as $\frac{9-9}{9-9}$, = 36; so agreeing with Fabricius. But if we are so slow in arriving at certainty respecting the dental apparatus of the beluga, when are we, by this means, to determine species in any of the other Cetacea?

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[1] *Voyage de la Coquille*, t. i. p. 184.

[2] *Voyage de M. Freycinet.* Zoologie, p. 86.

Sir Charles Giesecké describes the white whale as a migratory animal, which visits Greenland every year regularly about the end of November. He remarks that, next to the seal, it is the most useful animal captured by the natives, as it comes at a season when their provisions are extremely scanty. It arrives in herds, in stormy weather. It is taken by harpoons and strong nets; in the latter case the nets are extended across the narrow sounds between the islands, and when a shoal is thus interrupted in its course seaward, the individuals are attacked with lances, and great numbers are frequently killed. The flesh is somewhat similar to that of beef, of a bright red colour, though somewhat oily. According to Hans Egede, "when it is marinated with vinegar and salt, it is as well tasted as any pork whatever; the fins also, and the tail, pickled or sauced, are very good eating, so that he is very good cheer. The oil is of the whitest, best, and finest quality."[1] Some of the internal membranes are used for windows, and some as bed-curtains; the sinews furnish the best sort of strong thread.

GENUS (*i.*) DELPHINAPTERUS, Cuv. Less. Distinguished from the dolphins by having no dorsal-fin, and from the beluga by having a slender beak, flattened transversely, and separated from the head by a marked furrow.

D. Peronii, Cuv. Less. *Delphinus Peronii*, Lacép. Desm., No. 771, D. *Leuco-grampus*, Peron. *D. Chilii* of Kotzebue. (See Plate XVI., figure 19.) Snout obtuse, depressed at the extremities and edge, thus forming a short beak; pectorals and tail large; colour above of a deep bluish-black, beneath brilliant white, except the edge of the pectorals, which is black. Length between five and six feet. Teeth $\frac{39-39}{39-39} = 156$, all slender and very pointed. High southern latitudes are the resort of this species. The historian of the voyage of Baudin met with them to the south of Van Diemen's Land; Dr Quoy saw them near New Guinea, as did M. Lesson, off Magellan's Straits and the Falkland Islands. Many of them, according to the last named author, surrounded the corvette in January 1823, on the vessel entering the Southern Ocean, and one was harpooned by the sailors, which enabled him to give a more accurate account than any previously supplied. It is elegant in its form, regular in its proportions, sleek, and especially remarkable from appearing to be covered with a black cloak. Its snout, as far as the eye, is of a silky and silvery whiteness, so are the sides and pectorals, the abdomen, and part of the tail. A large scapulary of a deep bluish-black colour, rising at the eyes, where the white appears like a cross, is pointed and bent on the flanks so as to cover the upper part of the back only. The iris is of an emerald-green.

D. Commersonii, Cuv. Less. *Delphinus Commersonii*, Lacèp. Desm. 772. *The Jacobite* of the French. Snout flat and slender; body generally silvery-white; the snout, tail, and pectorals tipt with black; about the size of the common porpoise. Commerson, who regards this as one of the most beautiful inhabitants of the ocean, encountered it in the Straits of Magellan. Lesson met with it at the Falkland Islands.

D. Senedetta? Lacèp. This species is rejected by Cuvier.[2]

D. Epiodon? Rafinesque Smaltz, Desm., 786, **F. Cuv.** Body elongated, attenuated posteriorly; snout rounded; lower jaw shorter than the upper; many obtuse teeth, which are all alike in the upper jaw; none in the lower. No dorsal-fin. This animal was taken in the Sicilian Seas in 1790, and Rafinesque seems to have described it from a drawing. We have no further information respecting it.

It may here be remarked, that we have now discussed to the extent our limits will allow our first subdivision, consisting of Cete with ordinarily proportioned heads, and numerous teeth; it includes nine genera, and about fifty species. The direction of the facial line has chiefly, though not solely, regulated us in this avowedly artificial, and, it should not be forgotten, not very important arrangement of genera. We shall here supply a tabular view of the classification of the whole of the preceding subdivision:—

A includes those which have a dorsal fin.

Genus *a.*	Beak long, cylindrical, with molar-like teeth, . . .	*Inia.*
b.	Facial line of nearly uniform slope, beak peculiarly long,	*Soosoo.*
c.	Facial line of nearly uniform slope, beak or snout short,	*Delphinorhyncus.*
d.	Facial line marked by a sudden fall, beak short, .	*Delphinus.*
e.	Facial line of uniform slope, no beak, snout short, .	*Phocœna.*
f.	Head globe-shaped. No beak, no snout, . . .	*Globicephalus.*

B Those which have two dorsal fins.

g.	. . . . .	*Oxypterus.*

C Those which have no dorsal fin.

h.	Head globe-shape (from only a single species, called) .	*Beluga.*
i.	Having a beak, from απτερος "without a fin." . .	*Delphinapterus.*

SUBDIVISION II.—HETERODONTES. Head of ordinary proportion. Teeth few, and of various forms,—sometimes wanting. Blow-hole single.

Ever since Cetology has been studied as a science, the teeth, as in the other orders of Mammalia, have received the most marked attention. The two great orders into which Lacèpéde divides the *ordinary* Cete (which alone he considers), are founded on the fact, that some possess teeth, while others want them; and three of his ten genera repose solely on the peculiarities of the dentition. Since his time increased attention has been paid to these important parts. Blainville introduced the term HETERODON,—in which subdivision he includes those genera of which the teeth, in number, form, and situation, are various and in some respects anomalous. Sometimes, as in the Narwhal, they are scarcely in the mouth at all; and several genera are believed to be still more destitute of teeth. Desmarest and Lesson have followed in Blainville's track, and pursuing the same course we shall now discuss, under the name of HETERODONTES, a perplexing and somewhat anomalous group. It includes the *Narwhal*, the *Diodon*, the *Hyperoodon*, the *Aodon*, and the *Ziphias*,—which last comprehends some of the most important fossils which have been discovered.

GENUS NARWHALUS, Lacép., Cuv., Desm. *Monodon*, Lin., Bon. *Sea Unicorn* of whalers. This genus has no teeth properly so called, but only two long tusks straight and pointed, implanted into the outer maxillary bones, and projecting forwards in the axis of the body. It has no dorsal fin.

This long established genus was formerly made to include several species. Bonnaterre had two, and Lacèpéde and Desmarest three; the first and last of these, viz.—*N. vulgaris?* Lacép., Desm. No. 707, *Monodon monoceros*, Fab., Linn., *Narwhal*, Bon.; and the *N. Andersonii?* Lacèp., Desm. No. 789, are now rejected as having been introduced on insufficient grounds. There remains, therefore, only one species, viz.

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[1] *Description of Greenland.*

[2] *Règne Animal*, 291.

N. microcephalus, Lacép., Desm. No. 788, Dr Fleming. *Monodon monoceros*, Linn., Cuv., &c. *Sea Unicorn.* (See Plate XVII., figure 2.) This singular creature has rarely two tusks developed at the same time; the single tusk or horn (as it is called) has usually spiral markings, though these are sometimes absent; its length is from seven to ten feet; and that of the whole animal twice or thrice as much. The head is round and suddenly truncated; body slender; no dorsal fin; pectorals short; eye small; colour generally light-grey, variegated with darker spots. Vertebræ 7, 12, 35, = 54 (Scoresby); ribs twelve pair. The length of the narwhal is usually stated to be about fifteen or sixteen feet, which is to be understood exclusive of the tusk; so that, with this striking appendage, it reaches to from twenty to twenty-seven feet. Besides the elongated tusk, like a spirally twisted spear, there is literally no other teeth. When very young, the germ of a tooth can be discovered on each side of the mesial line, the subsequent elongation of one of which produces the sharp weapon of the adult. Sometimes both germs are developed, and produce two horizontal and diverging spears. Among a considerable number of instances which might be adduced, we mention only one of this more perfect development, which is preserved in the Museum of Roeding at Hamburgh. In this specimen, when they start from the bone (see Plate XVII., figure 1), the tusks are only two inches apart; but they steadily diverge till their points are thirteen inches asunder. The left tusk is seven feet five inches and the right seven feet long. It much more frequently happens, however, that only one of the germs grows, while the other becomes almost obliterated, or remains shut up in the bone, like an inert osseous nut. It is curious that the tusk is usually found on the left side,—a fact for which we believe that no sufficient reason has yet been assigned. At one time it was stated that the tusks were peculiar to the males; this, however, is now found to be incorrect, and it seems doubtful whether they are not as common in the one sex as the other. Fabricius' account is probably the correct one, "*Cæterum, tam feminæ, quam mares dentatæ.*" Two uses of the horn may be inferred from the statements of Dr Scoresby:[1] one, that it is occasionally employed in breaking the thinner ice, whereby the narwhal can more easily carry on respiration than it otherwise could; and the other, that, by the horn, it attacks its prey, first killing the great fish on which it is to feed, because, from the smallness of the mouth, it could not possibly devour them until it had put an end to all resistance.

The sea-unicorn is regarded by the Greenlanders as a migrating animal. Its favourite resorts seem to be among the ice-islands of the pole, and the creeks and bays of Greenland, Davis' Straits, and Iceland. The natives regard it as the precursor of the great *Mysticetus*, and, as soon as it is noticed, they prepare in earnest for the fishing of that vast monster. Narwhals are quick, active, usually inoffensive animals, which swim with considerable velocity. When harpooned they dive in the same manner, and almost with as much rapidity, as the true whale, but not to the same depth. They generally descend about 200 fathoms, then return to the surface, and are despatched with the lance in a few minutes. The blubber supplies about half a ton of oil, which is regarded of first-rate quality. The Greenlanders consider both the oil and flesh as very delicious nourishment. At a time when the origin of the horns of these animals was less known, and when they were more rare than now, they were considered as invaluable. The physician, and still more the charlatan, employed them, and superstition converted them to its use; for it is stated that the monks in various convents procured the *true* horn of *the* unicorn, which was believed to be endowed with unheard-of powers, and obtained for them far and near the credit of curing the most inveterate diseases. The ivory is esteemed superior to that of the elephant; in the words of Giesecke, it far surpasses it in all its qualities. It is said that the kings of Denmark possess a magnificent throne made of these precious horns, which is preserved with great care in the castle of Rosenberg. They still form a highly valued article of trade.

ANARNACUS, ? Lacép. We shall here notice the *Anarnak*, the fourth genus of Lacépède, the fifth of Lesson, the nineteenth species of Fabricius,—a kind of Monodon according to Bonnaterre, and of Heterodon according to Desmarest. The characters are, two small teeth at the extremity of the upper jaw, and no traces of any other teeth in either jaw.

Anarnacus Groenlandicus? Lacép. Less. *Monodon spurius*, Fab. Bon. *Delphinus Anarnak*, Desm. No. 780. The two teeth are scarcely an inch in length, obtusely conical, slender, and curved at their summit; body elongated; whole size inconsiderable; a dorsal-fin; colour black; the flesh said to possess a laxative property. This genus rests solely upon the authority of Fabricius. He says it frequents the high northern seas, and seldom approaches the coast.

GENUS DIODON, Lesson. The lower jaw supplied with two teeth only, the upper having none; the lower jaw the longer and stronger, somewhat convex; forehead depressed.

D. Sowerbyi, Less. *Delphinus Sowerbyi*, Blain., Desm., No. 785, Fr. Cuv. *Physcter bidens*, Sowerby. (See Plate XVII., figure 5.) Lower jaw longer than the upper and stronger, with two short *lateral* teeth; upper jaw sharp, let into the lower, having two impressions corresponding to the teeth; eye small; spiracle lunated, horns pointed forward; colour black above, nearly white beneath, marked with streaks. Sowerby's specimen was sixteen feet long and eleven in circumference at the thickest part. Dorsal fin over the vent. This animal was cast ashore near Brodie-House, Elginshire.[2] Its ordinary habitat and habits are wholly unknown.

D. Desmaresti, Risso. Less. Fr. Cuv. Upper jaw short and without teeth, lower much longer, convex, and having near its extremity two large conical teeth, three inches long, one broad; eye small; pectorals short; dorsal fin over the vent; tail large and festooned; upper portion of the body of the colour of polished steel, with a number of white streaks arranged without regularity; belly white; inside of the mouth bluish-black. Risso's specimen was fifteen feet long. According to the naturalist of Nice, who alone has described and drawn this animal,[3] it affects the deep waters of the Mediterranean, and comes towards the coast in the months of May and September. It very much resembles the preceding.

GENUS HYPEROODON, Lacép. Cuv. Less. Fr. Cuv. Three great bony maxillary and occipital crests, separated by deep furrows, which rise over the cranium and occasion a remarkably rounded and prominent forehead; beak short and very strong; *palate supplied with a number of small false and tuberculated teeth?* blow-hole crescent-shaped, horns pointing forward.

H. Honfloriensis, Less. *Delphinus Hyperoodon*, Desm. No. 784. *H. Butskof*, Bon. Lacép.; including also *D. bidentatus*, Bonnat. *D. Diodons*, Lacép. *D. Hunterii*,

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[1] See some interesting remarks in a *Journal of a Voyage to the Northern Whale-Fishery*, 1823.

[2] Sowerby's *Brit. Miscel.* 1806. We beg to observe that the generic title of DIODON is extremely ill-chosen,—seeing that it has been long ago applied by all naturalists to a genus of plectnognathous fishes.

[3] *Hist. Naturelle de l'Europe Mérid.* Nice. 1826. T. iii. pl. 3.

Desm. 782: called *Bottle-nosed whale* by Hunter, plate 10. *Bottle-headed whale* of Dale. (See Plate XVII., fig. 8). False teeth in the upper jaw, and, allowing these have no existence, still the name has been affixed by Cuvier to a genus which undoubtedly exists, and which possesses marked peculiarities in the prominence of the forehead, and the shortness and flatness of the beak, produced by the maxillary crest. The head is higher than it is broad; the pectorals are very small; the dorsal fin, but little developed, is within a fifth of the length from the tail. Colour brownish-black above, verging towards white beneath. Usual dimensions from sixteen to forty feet. Vertebræ 7, 9, 26, in all 42 (Jacob); ribs 9 pair. Two strong teeth at the extremity of the lower jaw.

This genus was admitted upon the authority of M. Baussard, an officer of marine, who examined two individuals, mother and cub, which were stranded near Honfleur, and who, with laudable zeal, published an account of them in the year 1789.[1] The circumstance on which rested the claim of these specimens to be considered generic was the total want of teeth in either jaw, and their having the upper jaw and palate furnished with small unequal and hard points, which were about half an inch long in the cub, and somewhat larger in the mother. Baussard's memoir appeared two years later than Mr Hunter's description of his *B. bidentatus*,[2] which was admitted as distinct by Bonnaterre, Lacépède, &c. Hunter says nothing of false teeth in the palate, and mentions that two strong and robust teeth existed at the extremity of the lower jaw. These, then, were long regarded as two species. Bonnaterre, in describing Baussard's specimens, very unaccountably assigned to them two teeth in the lower jaw,[3] and thus very naturally misled Lacépède, Illiger, and for a time even Baron Cuvier.[4] It was probably when holding this opinion, that Cuvier, in visiting Mr Hunter's museum, and examining the head of his *Bidentatus*, came to the conclusion that Baussard's and Hunter's specimens were one and the same species, belonging, however, to a genus distinct from all others. He attached the title of *Hyperoodon* to both.

H. Chemnitzianus? D. Chemnitzianus, Desm., Blainv. Length twenty-five feet; two teeth at the extremity of the moveable or lower (but Desmarest has it upper) jaw; upper jaw, much less thick and strong; body wholly black. A considerable quantity of spermaceti was taken from the head of this species which was captured near Spitzbergen in 1777. It is the *Balæna rostrata?* of Chemnitz, which Blainville and Desmarest have classed among the Heterodons, and which Cuvier suggests would be better united with the present genus. But in truth the description is so short that nothing satisfactory can be made of it.[5]

Genus Aodon, Lesson. No teeth; no tubercles on the palate; no whalebone; body fusiform; forehead prominent; jaw in a continuous line with the forehead.

A. Dalei, Less.; *Delphinus Dalei*, Blain., F. Cuv.;[6] *D. edentulus*, Schreber, Desm. 783; *Delphinorhyncus micropterus*, Cuv.[7] (See Plate XVII., figure 6.) Body fusiform; some appearance of a neck; forehead prominent; spiracle curved forwards; jaws prolonged in form of a subcylindrical beak, and in the same plane with the facial line, the upper somewhat shorter than the lower; no teeth, or only rudimentary; no rugosities on the palate; pectorals and dorsal very small; tail broad; colour shining-grey, dark above, light beneath; vertebræ seven, nine, and from fifteen to twenty more; ribs nine; maxillary and intermaxillary bones rising high above the frontal. This beautiful animal stranded itself near Havre; its resorts, habits, &c. are wholly unknown. The species was originally founded on the *Bottlehead* of Dale, and designated as *D. edentulus* by Schreber, Blainville, and Desmarest. The name was applied afresh to a specimen stranded near Havre in 1825, and examined by Drs Surirray and Blainville. If Hunter was right in saying that his *Bidentatus* was the same as Dale's, then the authors last quoted were incorrect in associating that name with the Havre specimen. This was Cuvier's opinion, who says (in *Règ. An.*) that the name was "*très impropre.*" Nevertheless we retain it, as we believe the species has been accurately described under that designation.

The Genus Ziphias being fossil, we omit. Cuvier states that their craniums ally them to the Cachalots, and still more to the Hyperoodons. He has distinguished three species, all of which appear to be destitute of teeth.

Subdivision III. Great-headed Whales.

We now advance to the last subdivision of the ordinary whales, which is distinguished from the others by having the head much larger than the usual proportions, amounting to one-fourth, or even to one-third of the whole bulk. Though this section includes by far the most important animals of the order, yet the number it contains is small, extending to but three genera, and about twice as many ascertained species. All of these, from their extraordinary magnitude, and the majority from their extreme value, have from time immemorial engaged the liveliest and most general interest; and hence, notwithstanding their gigantic size, their structure is better known, and their habits and disposition better ascertained, than those of most others of the race.

Genus Cachalot,[8] Bon. Desm. Cuv. *Physeter*, Linn. Head nearly one-third of the whole size; blow-hole single; no baleen; no teeth, or only rudimentary, in the upper jaw; lower jaw narrow, elongated, received into a furrow in the upper one, armed on each side with a range of strong teeth. Produces the *spermaceti* and *ambergris* of commerce.

C. macrocephalus, Cuv. Bon. Lacép. *Physeter catodon*, Linn. *The Spermaceti Whale.* (See Plate XVII., fig. 11.) One or more humps on the back; lower jaw having from 20 to 23 teeth on each side, a few rudimentary ones hid under the gums in the upper jaw; length 80 feet; colour greenish-black above, whitish beneath. Vertebræ, 7, 14, 38, = 59.

Some of our readers may perhaps be surprised, that under the generic term Cachalot we introduce to their notice only a single species. This we do, not because we deny the existence of others, but because these have not hitherto been accurately described or established. Desmarest some years ago admitted three sub genera and eight species; and Lacépède has three genera and eight species, including his cachalots, physalus, and physeter.[9] Every one who, previous to our own days, had attempted to reconcile the many contradictory accounts which have been given of this extraordinary animal, seems in his turn to have been foiled; and it was reserved for Cuvier to cut at all events, if not to unravel, the entangled knot. He remarks: " The history of this animal is so perplexed, so many beings have been confounded with it, and the species have been so wantonly multiplied, that to obtain more precision on the subject, I have been obliged to review, chronologically, every thing that naturalists have written concerning it." And after making this review, he concludes, " Will it now be regarded as great temerity in me, after having produced the ideas of so many learned men, to maintain that up to the present time, there is no ground to suppose that there is more than a single species of Cachalot?"

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[1] *Journal de Physique*, 1789.

[2] *Phil. Trans.* 1787.

[3] Lesson, 130. Though this is clearly asserted by Lesson, we do not find the mistake in the *Encycl. Method.* It is very apparent in Lacépède's *Cetacées*, p. 320.

[4] *Règ. Animal*, 1817, t. i. 281.

[5] See *Oss. Foss.* t. v. 325. Less. 120. Fr. Cuv. 244.

[6] *Mammifères.*

[7] *Règne Animal*, t. i. 288.

[8] From *Cachou*, a tooth, in the Basque tongue.

[9] We shall here exhibit the older classification by copying that of Lacépède.

I. Genus *Cachalot.* Having blow-hole at the extremity of the snout.
  1. Subgenus. Those which have a bump or bumps on their back. 1st sp. *C. macrocephalus.* 2d, *C. Trumpo.* 3d, *C. Swinwhal.*
  2. Subgenus. 4th sp. *C. albus.*
II. Genus *Physalus.* Having blow-hole on the head, not at the extremity of the snout. 5th sp. *P. cylindricus.* Having a bump on the back.
III. Genus *Physeterus.* A fin on the back. 6th sp. *P. Microps.* 7th, *P. Orthodon.* 8th, *P. Mular.*

We take our description very much from that supplied by Cuvier.[1] It is one of the largest Cetacea, attaining the length of 70 and 80 feet; its head is very large in all its dimensions, and the length of that part does not appear to have been much exaggerated when stated to be about a third of the whole body; the snout is very obtuse, and apparently truncated; the lower jaw, very narrow, is received between the upper lips as in a furrow, the teeth entering, when the mouth is shut, into cavities on the edge of the palate. The blow-hole, 12 inches long, in the form of an *ſ*, is on the anterior extremity of the head, in the centre of a round protuberance, formed of thick fibres, which act as a sphincter. The pectorals are small and obtuse; there is a small dorsal protuberance only, far down the back, and sometimes two or three smaller ones; the tail is very large. The colour above is a blackish and somewhat greenish-grey; below it is whitish, as also round the eyes. The immense cavity at the upper part of the head, covered only by a tendinous but very resisting integument, is divided interiorly into compartments, also tendinous, which communicate with one another, and into great cells filled with oil, which is fluid when the animal is alive, but after death assumes the concrete form with which we are familiar under the name of spermaceti. This substance was long absurdly regarded as the brain, which, in truth, occupies a very small space in the interior of the cranium. The ambergris again, is found in the intestinal canal, but in what precise part, and under what exact circumstances, has not yet been ascertained.[2]

From the popular and highly interesting statement of Mr Beale,[3] we learn that the blubber on the breast of a large whale is about 14 inches thick, and on most other parts of the body from 8 to 11. This covering the southern whalers call the *blanket;* it is of a yellow colour, and when melted down yields the sperm oil. He states, that the opening of the ear is of sufficient size to admit a small quill. The throat is capacious enough to give passage to the body of a man, in this respect presenting a strong contrast to the contracted gullet of the Greenland whale. According to Mr Beale, the peculiarity of the sperm-whale which strikes every beholder, is the unwieldy bulk of the head; but this, instead of being an impediment, is conducive to its agility, for the greatest part of it containing oil, the head receives a tendency to rise so far above the surface, as to elevate the blow-hole for the purposes of respiration; and should the animal wish to increase its speed to the utmost, the narrow lower portion of the head, which bears some resemblance to the cut-water of a ship, is the only part exposed to the resistance of the water, and it is thus enabled to press its ponderous way, with the greatest ease, along the ocean. " LORD, how manifold are thy works! in wisdom thou hast made them all." " They that go down to the sea in ships, that do business in the great waters; these see the works of the LORD, and his wonders in the deep."

Mr Beale's observations on the swimming of this whale are curious. He states that, when undisturbed, it passes tranquilly along, just below the surface of the water, at the rate of about three or four miles an hour, its progress being effected by a gentle oblique motion of the tail from side to side. When proceeding at this rate, the body lies horizontally; the water, somewhat disturbed by its progress, is known by the whalers under the name of " white-water," and from its appearance, an experienced eye can, from a distance of several miles, judge of the rate at which the whale is advancing. In this mode of swimming, it is able to attain a velocity of about seven miles an hour. When it swims at a more rapid rate, the action of the tail is altered, the water is struck directly upwards and downwards, and each time the blow is made with the lower surface, the head sinks down eight or ten feet; and when the blow is reversed, it rises out of the water, presenting to it only the sharp cut-water portion. This mode of swimming is what is called *going-head-out*, and in this way the whale can attain a speed of 10 or 12 miles an hour, which is probably its greatest velocity.

The sperm-whale is remarkably distinguished from its congeners by its *blowing.* If the water is smooth, the first part observed is the hump, projecting two or three feet above the surface; at very regular intervals of time, the snout emerges, at the distance of forty or fifty feet; from the extremity of the snout the jet is thrown up, and when seen from a distance, appears thick, low, bushy, and of a white colour. It is formed, according to Mr Beale, by the air expelled forcibly through the spiracle, acquiring its white colour from minute particles of water previously lodged in the external fissure. It is projected at an angle of 45°, in a slow and continuous manner, for about three seconds, and may be discovered at the distance of 4 or 5 miles. This leviathan is, like the mysticetus, remarkably timid, and is readily alarmed by the approach of any unlooked-for object. When frightened it is said by the sailors to be " gallied," probably galled; and in this state it performs many actions in a manner very different from the usual mode. One of these is what is called " sweeping," which consists in moving the tail slowly from side to side on the surface of the water, as if feeling for any object that might be near. This whale has also an extraordinary fashion of rolling over and over on the surface, especially when harpooned; in which case it will occasionally coil an amazing length of rope around it. But one of its most surprising feats—as it is of those of all the larger genera—is leaping completely out of the water, or " breaching," as it is called;—a practice which, from its dangerous results to those around, is regarded by mariners as far " more honoured in the breach than the observance." The mode in which this appears to be done is by descending to a certain depth, and then making several powerful strokes with its tail, thus imparting great velocity to the body before it reaches the surface, when it darts completely out of the water. It seldom breaches more than twice or thrice at a time, and in quick succession; the performance may be seen at the distance of six miles from the mast head. We once witnessed a Scotch whale performing a similar feat in Loch-fine, between the loved shores of Minard and Castle Lachlan.

The sperm-whale seems now to have nearly vanished from the northern hemisphere, though it is frequent in numerous places in the southern. In the year 1791, seventy-five vessels belonging to Britain were engaged in the trade, whilst in 1830 only thirty-one ships were sent out, all from the port of London, with an aggregate burden of 11,000 tons, and 937 men. On its introduction into commerce *spermaceti* was chiefly employed in medicine, in which its use is still continued; and it is also freely used in the cosmetic art. Its largest and most valuable application, however, has long been in the manufacture of candles, in which it maintains a rivalry with wax, as cheaper and not less elegant.

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[1] *Oss. Fossil.* t. v. p. 339.

[2] For a somewhat minute and valuable account of the anatomy of a sperm-whale, which was cast ashore on the Yorkshire coast in April 1825, see a paper by James Alderson, Esq. in the second vol. of the *Trans. of the Cambridge Phil. Soc.*

[3] *Observations on the Natural History of the Sperm-Whale.* Lond 1835.

Ambergris, according to its quantity, is a peculiarly valuable product of the sperm-whale. The majority of sperm-whales, however, do not yield it. Sometimes it sells in London at about L.1 an ounce, but frequently two or three voyages are accomplished, and successfully too, without any ambergris being obtained. It is seldom or never found in young fish, but only in those of full size, or rather of great age. It is generally considered the result of some diseased process in the intestinal canal; the quantity obtained, therefore, is very various. Sometimes 50 lb. have been extracted from a single individual. Ambergris is frequently found in considerable quantities on the sea-shore, especially in the Indian seas. It is highly esteemed by the orientalists. With us its use is confined almost wholly to the perfumer.

C. sulcatus? Abel Rémusat. Lacépède. Reported to have a furrow below the lower jaw, and to frequent the Chinese seas.[1]

Aggadachgik? Tschicduk? Tschumtschugagah? Pallas and Chamisso. These are alleged Kamtschatkan varieties. See Less. and Fr. Cuv.

GENUS BALÆNA, Lacép. Cuv. Less. The *right-whale* of northern fishers. No teeth; blow-holes double; no dorsal fin; long whalebone or baleen in the upper jaw; blubber thick and highly productive of oil.

B. mysticetus, Linn. Desm. (No. 798.) *True whale*, Bon. Lacép. *Greenland whale* of Fab. and of fishers. *B. borealis*, Klein. (See Plate XVII., figure 12.) Length about 60 feet; body of vast circumference; fanons more than 300 on each side of upper jaw, extending from 10 to 15 feet in length; colour black above, and partly white beneath. Vertebræ 7, 13,—?[2]

In former times there was much exaggeration as to the dimensions of this whale, 80 and 100 feet being assigned as a frequent size, and 150 and 200 feet as not uncommon. Some of the ancients stated, that it attained even a much greater length. From the researches, however, of Dr Scoresby, it seems irrefragably established, that the mysticetus never exceeds nor has exceeded 65 or 70 feet.[3] That excellent observer was personally concerned in the capture of 322 whales, not one of which exceeded 60 feet. It is thickest a little behind the fins, whence it gradually tapers in a conical form towards the tail, and slightly towards the head. The head is remarkably large, forming nearly one-third of the whole bulk. Its under part is flat, and measures from 16 to 20 feet in length, and from 10 to 12 in breadth. When the mouth is open it presents a cavity as large as a small apartment, and capable of containing a ship's jolly-boat full of men.

The mysticetus has no dorsal fin, the pectoral fins are about nine feet long and five broad. The tail is semilunar, indented in the middle. On the most elevated part of the head, about sixteen feet from the extremity of the jaw, are situated the blow-holes, consisting of two longitudinal apertures, similar to the holes in the body of a violin, from eight to twelve inches in length. The mouth, in place of teeth, contains two extensive rows of baleen, commonly called *whalebone*, suspended from the upper jaw and sides of the crown bone. The plates are generally curved longitudinally, and give to the roof of the mouth the form of an arch. They inclose the tongue between their lower extremities, and are themselves covered by the lower lip. There are upwards of 300 of these plates on each side of the jaw; they are longest in the middle, whence they gradually diminish away to nothing both in front and behind. The tongue is incapable of protrusion; and the throat is remarkably narrow,—according to Sir C. Giesecké, not exceeding an inch and a half in width. The colour of the true whale is mostly velvet-black, with white in some parts underneath, and a tinge of yellow. The blubber, constituting the most valuable part of the animal, forms a complete wrapper round the whole body from eight to twenty inches thick.

Being somewhat lighter than the medium in which it swims, the Greenland whale can remain on the surface with its spiracles above water, without any effort or motion; and it is thus sometimes found asleep upon the waves. Though bulky and clumsy, it is capable of making great exertion. A whale extended motionless on the surface can sink, in the space of five or six seconds, beyond the reach of its human enemies. Dr Scoresby has observed a whale descending, after it had been harpooned, to the depth of a quarter of a mile, with the average velocity of seven or eight miles an hour. The usual rate, however, at which they swim when on their passage from one station to another, seldom exceeds four miles an hour. Sometimes they leap entirely out of the water, and sometimes they throw themselves into a perpendicular position, with their heads downwards, and waving their tremendous tails on high in the air, beat the water with awful violence,—the sound reverberating to the distance of two or three miles. This feat is denominated "lob-tailing." They usually remain at the surface to breathe, about two minutes—seldom longer; and during this time they blow eight or nine times, and then descend for an interval usually of five or ten minutes, although sometimes, when feeding, of fifteen or twenty. When harpooned or apprehending danger, the period is greatly prolonged. The food of these animals, so vast and strong, is too remarkable not to claim a moment's attention. They have no teeth, and hence we at once perceive that they cannot prey either on the smaller of their own kind or on fishes; and their throat is so narrow that they could scarcely dispose of such a morsel as might be swallowed by an ox. Their well provided pasture grounds, however, exhibit to the contemplation of the curious one of the most wonderful manifestations of beneficence and power. Vast portions of those spaces in which the whale is found, consist of what is called green-water; as there is yellow and red water, in other parts of the ocean. This was examined by Captain Scoresby in 1816, and to his astonishment he found that it obtained its colour from the presence of countless millions of animalcules, most of them invisible without the aid of the microscope, and of which the greater number consisted of a species of medusa. These minute creatures are not the immediate food of the whale; they form, however, the prey of the various shrimps, small crustacea, cuttle-fish, &c. upon which the monster of the deep is supported. When this whale feeds it swims with considerable velocity below the surface, with its jaws widely extended. A stream of water consequently enters its mouth, and along with it large quantities of minute crustaceous and molluscous animals; the water flows out again at the sides, but the food is entangled by the baleen or whalebone, which, from its compact arrangement, and thick internal covering of hair, does not allow a particle to escape, even of the size of the smallest grain. The mysticetus, though often found in great numbers, can scarcely be said to be gregarious;

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[1] See *Mem. du Museum*, t. iv.

[2] Giesecké.

[3] *Edin. Phil. Journ.* vol. i.

for it generally occurs either solitary or in pairs, except when attracted to the same spot by an abundance of palatable food, or a choice situation among polar icebergs.[1]

B. Nordcaper ?, Anderson, Bon., Lacép., Desm. (No. 799.) *B. glacialis ?*, Klein. We reject this species, as established by mistake on insufficient grounds.[2]

B. antarctica, Delalande, Cuv., Desmoul., Lacép., Fr. Cuv. Usually from forty to fifty feet long; colour wholly black; line of the forehead more depressed than in the *mysticetus*; pectorals longer and more pointed. Vertebræ 7, cervical, all anchylosed, 15 dorsal, others 37, in all 59. This species, nearly up to the present period, has been confounded with the preceding and probably we might have been still ignorant of the difference, had not M. Delalande, during his residence at the Cape of Good Hope, prepared one of these animals, and transmitted its skeleton to France, where Cuvier soon detected its specific characters. The whale of the Southern Seas is decidedly smaller than that of the north, measuring only from thirty-five to forty-five feet, though sometimes extending to fifty. Its baleen, owing to the great curve of the upper jaw, appears to be relatively longer, usually reaching to about nine feet in a fish of forty feet. Whilst the pectoral fins appear longer and more pointed, the lobes of the tail are less marked than in the preceding species. This whale is found in the bays of Terra del Fuego, and on the western coast of South America; it also occurs around New Holland, as well as along the African shore. It visits the Cape of Good principally in June. Its capture is more easily achieved than that of the great Greenland species.

The ensuing quotations seem to us to indicate the existence of other still undetermined species in the Arctic Regions. "The whales," says Dr Scoresby, "seen in the spring in lat. 80° N., which are usually full grown animals, disappear generally by the end of April. Those in 78° are of a mixed size; such as resort to fields in May and June are generally young animals. Those seen in 76° are almost always of a very large kind. In some the head measures four-tenths of the whole length, in others scarcely three-tenths; in some the circumference is upwards of seven-tenths of the length, in others less than six-tenths. It is probable the difference in the appearance of the heads, and the difference of proportion existing between the heads and bodies of some mysticetæ, are characteristic of different species or subspecies. Those inhabiting lower latitudes have commonly long heads and bodies compared to their circumference, moderately thick blubber and long whalebone; those of the mean fishing latitudes, that is 78° or 79°, have more commonly short broad heads, compared with the size of the body."[3] "It is certain," observes M. Frémenville, "that the fishers confound many species which are still unknown. On my expedition towards the North Pole, in 1806, I remarked there were great differences in the shape of the tails of the whales which were taken, and which, without doubt, belonged to species not yet accurately ascertained." It is also more than probable that another occurs in the southern seas. "I am certain," says Baron Cuvier, "that at least a third species exists at the Cape of Good Hope, seeing we have satisfactory knowledge of vertebræ, which, with the characters of the subgenus (without dorsal-fin), present also distinct specific characters."[4]

B. Gibbosa ? Bon., Lacép., Desm., No. 801. *Scrag-whale* and *Hunchback* of Dudley and the English; *B. à bosses* of the French; *Knoten-fisch* of the Germans, and of Anderson.

B. Nodosa ? Gmel., Bon., Lacép., Desm., No. 800. *Humpback whale* of Dudley and the English; *Pflockfisch*, Anderson, Crantz, &c.

We cannot pass by these alleged species, so long and widely recognised, without a few remarks. They are classed together as subgenera of the *true whale* by Lacépede, Desmarest, and many others, whilst Bonnaterre associates them with the *Gibbar*. Cuvier throws doubts on the existence of all these species, remarking that their right to a place is founded upon some obscure passages of Mr Dudley's paper in the Philosophical Transactions. The *humpback* of Dudley (*B. nodosa*) should evidently be removed from the true whales, because, according to Dudley himself, it is a rorqual: "the humpbacks have longitudinal reeves from head to tail on their bodies and sides, as far as their fins, half way down their body."[5] The *Gibbosa*, again, he remarks, comes nearest the true whale in figure and for quantity of oil; and, according to Anderson, it produces as much oil as the Greenland whale. Though we cannot accurately characterize this *Gibbosa*, neither can we altogether reject it; and the following facts supply something like additional evidence of its existence. Captain Day, a most respectable southern fisher, mentions that he occasionally took humpbacks as well as sperm whales and finners;[6] and Captain Weddell also states that he met with humpbacks, besides sperm whales and finners.[7] Captain Colnett, likewise, whose voyage was undertaken to increase our knowledge of the southern fishery, and who had many whalers among his crew, familiarly speaks of the humpback, as well as of the other kinds; and humps are described by M. Abel Rémusat and Lacépède as occurring on the heads of the *Punctata* and *Nigra*, two alleged Japanese species. We hence infer that attention should still be directed to the kind called *Gibbosa*.

B. Japonica ? Rémus., Lacép., Desm., No. 802. Less.

B. Lunulata ? Rémus., Lacép., Desm., No. 803. Less.

These species are described by Lacépède in a paper read to the Institute in 1818, from Japanese designs communicated by Rémusat, and the characters are detailed in the *Mem. de Mus. d'Hist. Nat.* t. iv. 473. Their existence, however, is very doubtful.

B. Kulcomoch ? Pallas, Chamisso, Less., Fr. Cuv.

B. Ischikagluch ? Pallas, Chamisso, Less., Fr. Cuv.

Pallas describes these species of the Kamschatkan Seas with apparent accuracy in his *Zoograph. Rosso Asiatica*, as does also Chamisso, the naturalist of the Rurick.[8] They are, however, far from being satisfactorily established.

B. Physalus ? Lin. *B. Gibbar*, Bon., Desm., No. 804. *Physalis*, Scoresby. *Balænoptera Gibbar*, Lacépède. *Finfisch*, Anderson; *Razor-back* of whalers. Fin on the back, and no pectoral folds. There are no sufficient grounds for the admission of this supposed species, which seems to have arisen from some confusion with the rorquals.[9]

Genus Rorqualus,[10] Cuvier., Less., F. Cuv. (See Plate XVII., figure 13.) No teeth; a dorsal-fin; folds under the throat and chest; fanons in upper jaw, but short;

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[1] We cannot dismiss these slight notices of this important species, without referring the reader to Dr Scoresby's elaborate treatise on the *Arctic Regions*, which contains a most interesting history and description of the northern whale-fishery. Consult also the first volume of the *Edinburgh Cabinet Library*, entitled *Narrative of Discovery and Adventure in the Polar Seas and Regions.* Fourth Edition, 1835. We may further add, that the first tolerable figure of *B. Mysticetus* ever published was the capital one of Scoresby.

[2] *Oss. Fossil.* t. v. p. 360-5.

[3] *Scoresby*, i. 470; ii. 211.

[4] *Oss. Fossil.* t. v., p. 368.

[5] *Phil. Trans.* No. 387, p. 258.

[6] *Scoresby*, ii. 530.

[7] *Voyage to the South Pole*, pp. 29, 34, 182.

[8] *Kotzebue's Expedition.*

[9] *Oss. Foss.* v. 363-4.

[10] *Rorqual* in the Norwegian tongue means *whale with folds.*

blubber not thick, nor yielding much oil; blow-hole double.[1]

R. borealis, Less. *R. Boops*, Fr. Cuv. The *Great Northern Rorqual, Balæna Rorqualus*. Bon., Desm. No. 806. The general form of the body is that of an immense cylinder, largest at the head, and gradually diminishing to the tail; dorsal small, obtuse at the summit, placed opposite the vent; pectorals thin, straight, and pointed at the extremity; blow-holes not situated on the most elevated part of the head, but in advance of the perpendicular over the eye; the upper jaw descends rapidly towards the lower, is not so long, and much weaker; the baleen much shorter than in the mysticetus. Numerous folds cover the throat and chest, and extend to the abdomen. Colour black above, whitish underneath; inside of the folds pale red. Length from 100 to 110 feet. Vertebræ 7, 15, 42; = 64.

The northern rorqual is the largest of the whale tribe, the mightiest giant of the "great deep," and probably the most powerful and bulky of all created beings. Its head is to its entire length as one to four. It differs from the *mysticetus* in its body being proportionably longer and more slender, in its form being less cylindrical, in possessing a dorsal-fin, in its skin or blubber being much thinner (seldom exceeding six inches), and in its speed being greater, its action quicker, and more restless, and its conduct bolder. The blowing also is more violent, and its baleen much shorter and less valuable. The cause of this last important difference is very plain, and may be best illustrated by a glance at the accompanying engraving (see Plate XVII.), in which there is given a side view (figure 9) of the cranium of the mysticetus and (figure 10) of that of the rorqual. It will at once be seen that the upper jaw of the former is relatively larger, and much more curved; the intervening space in both is filled with baleen, which accordingly must be long in the mysticetus, and short in the rorqual, the longest laminæ seldom measuring four feet.

In Mr F. Knox's account of the great rorqual, we are informed that 314 plates were counted on each side; and that, on further examination, it was found that these invariably extended mesially only about fifteen inches, and were then succeeded by a vast number of smaller plates, which gradually became less and less, till finally they were converted into bristles; so that, correctly speaking, there were probably not fewer than 4000 or 5000 distinct plates of whalebone. This baleen, when recent, was highly elastic and soft, the fringed edge being as pliable as the hair on the human head, and thus forming a sieve of the most perfect kind. From the same source we also learn that the posterior arch of the palate was so large that it could admit a man, being thus like a great vestibule to the windpipe and gullet, which last was quite closed when first seen, and appeared as if it would admit with difficulty even the human hand.

The proper nourishment of this genus is not only the small medusæ, shrimps, &c. which form the food of the mysticetus, but also the medusæ of larger size, and substantial fishes such as herring, cod, and salmon. There seems no ground to question, that these whales often follow in the tract of various fishes, and devour them in quantities which it would not be easy to conceive. Thus M. Desmoulins states that *six hundred great cod, and an immense quantity of pilchards*, have been found in the stomach of a single rorqual.

The plicæ or folds from which the genus derives its name constitute a singular structure, the precise use of which has not hitherto been very clearly stated. John Hunter described it with his usual accuracy, and observed that it must increase the elasticity of the integuments of the part, but confessed he could not perceive wherefore this should be, or how it was made useful. Lacépède also particularly describes it, and it has since been generally noticed by subsequent authors. It consists of a number of longitudinal folds, nearly parallel, which commence under the lower lip, occupying the space between the two branches of the jaw, pass down the throat, covering the whole extent of the chest from one fin to the other, and terminate far down the abdomen. The external portion of these folds is of the colour of the neighbouring skin, whilst the parts which are infolded are of a more delicate hue, generally of a pale white, and in some species of a beautiful red colour. The simplest and probably the true account of the use of these folds is this: The rorqual has not, in the upper jaw, that large segment of a circle in which the *mysticetus* collects its food; but to compensate for this it has it in the lower; for, when it opens its prodigious mouth, the water rushing in opens these folds, and so forms a vast well, in which its supplies are collected. On shutting its mouth and contracting the folds the water is expelled, whilst the strainer formed by the baleen retains the captured fish, which, entangled as it were within the folds of an enormous net, become an easy prey.

This animal attains the vast length of from 100 to 110 feet,—Sir A. de Capel Brooke says 120,[2]—with a circumference of between 30 and 40, which is the same as that of the *mysticetus*. Dr Scoresby remarks, "that it seems apparently of the length of a ship, that is, from 90 to 110 feet;"[3] and it has more than once been actually measured at 105 feet. Its blowing is very violent, and may be heard in calm weather at a great distance. Though the species of this genus are sometimes at a distance mistaken for the mysticetus, yet their appearance and action are so different that they may be generally distinguished. They seldom lie quietly on the water when breathing, but usually move with a velocity of four or five miles an hour, and when they descend they very rarely throw up their tails into the air, which is the general practice of the other.

The rorqual occurs in great numbers in the Arctic Seas, especially along the edge of the ice between Cherie Island and Nova Zembla. Persons trading to Archangel have often mistaken it for the *right whale*. It is seldom seen amid much ice, and seems to be avoided by the *mysticetus*; and the whalers accordingly view its appearance with concern. It swims with a velocity, at the greatest, of about twelve miles an hour. It is by no means a timid animal. When closely pursued by boats it manifests little fear, does not attempt to outstrip them in the race, and merely endeavours to avoid them by diving or changing its direction.

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[1] The prevailing arrangement of the individuals included under this genus has for many years been that of Bonnaterre and Lacépède. It contained,

1. *B. Jubartes*, Klein., Bon.; *Balænopter. Jubart*, Lacép., Desm., 805; *B. Boops*, Lin.
2. *B. Rorqualus*, Bon.; *Balænopter. Rorqual*, Lacep., Desm. 806; *B. Musculus*, Lin.
3. *B. Rostrata*, Fab., Hunter: *Balænopter. Acuto-rostrata*, Lacép., Desm., No. 807.

Cuvier considers these three, along with the *Physalus* (above alluded to), as one species. For reasons which will presently appear, we retain the *Rostrata* as distinct; but Cuvier's remarks in reference to the others are extremely judicious. "When we examine the figures and descriptions on which these species rest, it will be found that there are no means by which we can assign them distinctive characters. When we come also to examine in detail the testimonies respecting them, we find no person who has seen more than one of them, I do not say at the same time, but even in succession; and each author is obliged to support himself upon the testimony of another. Almost the only distinction we can make out is the size which may be the result of age; so that we are disposed to doubt and deny their existence as distinct."—*Oss. Fossil.* t. v. 365-6.

[2] *Travels in Lapland*, p. 141.

[3] Thomson's *Annals of Phil.* vi. 314.

Cetacea.

If harpooned, or otherwise wounded, it exerts all its energies, flies off with the utmost velocity, and usually escapes. This great speed and activity render it a dangerous object of attack, whilst the small quantity of oil it yields makes it unworthy of the particular attention of the fishers. But though regular whalers usually decline the encounter, it is not so with the natives of the polar regions, whose wants compel them to make every exertion which promises the least success, and whose opportunities are frequently peculiarly favourable. Sir C. Giesecké states, in regard to the Greenlanders, that both men and women engage in the adventure,—the former in their keyacks, the latter in their bomiaks. The men in their light skiffs pursue the whale as closely as possible, and continue to throw as many harpoons and lances into him as they can, until he dies of loss of blood; and then all join their canoes, fasten to their spoil, and carry it home, when it is faithfully divided. In the words of the poet:

> Trained with inimitable art to float,
> Each balanced in his bubble of a boat;
> With dexterous paddle steering through the spray,
> With poised harpoon to strike his plunging prey;
> As if the skiff, the seaman, oar, and dart,
> Were one compacted body, by one heart
> With instinct, motion, pulse, empow'red to ride
> A human Nautilus upon the tide.

R. rostratus (see Plate XVII., figure 13), Knox. Lesson. *Balæna Rostrata*, Fab., Lin., Hunter, Des., 807, *Balænoptera acuto-rostrata*, Lacép., Scoresby.

This is the smallest of the genus, twenty-five feet being assigned as its extreme limits; fanons short and white, pectorals ovate, margins obtuse; dorsal over the vent; many deep folds under the throat and chest; colour black above, white beneath; interior of the folds red. For the undisputed establishment of this species we are indebted to the zeal and assiduity of Dr Knox. It is true that Fabricius described it with his accustomed elegance and precision; that Mr Hunter likewise met with and delineated it; and that Dr Scoresby's work contains an exact representation, supplied through Dr Traill. But notwithstanding all this, the details which were collected were so slight and meagre, that not only were much ignorance and error prevalent concerning it, but many naturalists (of whom Baron Cuvier, in 1823, was one, and Mr F. Cuvier, in 1836, was another) were led to doubt even its existence.

Dr Knox's specimen was taken in February 1834, near Queensferry, Frith of Forth. It was a young one, measuring only ten feet. On obtaining possession of it, Dr K. thought of suspending it horizontally, as in the posture of swimming. "By this means," he remarks, "the proper character of the head and mouth were given, and this so much altered the appearance of the animal, that the author thinks all previous views extremely incorrect, besides tending to mislead the naturalist as to the real capacity of the mouth of the genus, which is really very great. The lower part of the mouth is an enormous pouch or bag which, in the great northern rorqual, must at times contain an incredible volume of water."[1] We have yet to state how Dr Knox established the fact that the lesser rorqual ought to be considered as distinct. It was by means of the comparative osteology of the two species, which exhibited the following discrepancies:—

	Vertebræ.			
	Cervical.	Dorsal.	Remaining.	Total.
Great rorqual,	7	15	43	65
Lesser do.	7	11	30	48

Before laying aside Dr K.'s brief notice, we must introduce a few of his remarks. "Two bolster-like substances filled the blowing canals, which are drawn from them at the moment of breathing, by muscles provided for that purpose; the mechanism is admirable, and would sustain a pressure from above, though the animal were to descend thousands of fathoms." Again: "The cavity of the cranium, besides containing the brain and its membranes, inclosed also a very large mass of a vascular substance, closely resembling the erectile tissue: it filled a very large proportion of the interior of the cranium, extending from thence into the interior of the spinal column, three-fourths of whose cavity it also occupied, surrounding the spinal marrow and nerves." The olfactory nerves "were at least as large as those of man."

Cetacea.

The *R. rostratus* frequents the rocky bays of Greenland, especially during summer, and also the coasts of Iceland and Norway; sometimes, though rarely, coming into lower latitudes. In its habits it is very active, and its food consists of arctic salmon and of other fishes.

R. Mediterraniensis, Cuv.; *Balænoptera Mediterraniensis*, Less.; *R. musculus*, Linn., Lacép. Head remarkably rounded; upper jaw shorter than the lower; dorsal fin smaller, situated four-fifths down the body, and much beyond the vent; the folds extend to the vent; upper parts of the body bluish-black, gradually declining on the flanks, and giving place to a dull white beneath. Vertebræ, 7. 14. 40? = 61? For the specific character drawn from the osteology, see *Oss. Fossil.* t. v. 370. This species is not uncommon in the Mediterranean. One, seventy-five feet long, was stranded near St. Cyprien, Eastern Pyrenees, in 1828.

R. antarcticus, Cuv., Fr. Cuv., Delalande; *Balænoptera australis*, Less.; *Poeskop* of the Dutch at the Cape. Dorsal long and situated directly over the pectorals; a hump upon the occiput; the colour black above, and pure white beneath; the furrows under the throat and chest of a lively rosy hue. Vertebræ, 7, 14, 31; = 52. For specific characters of bones of the cranium, see *Oss. Fossil*, v. 372.

As we have seen that there is a *mysticetus* of the southern as well as northern seas, so within the last few years it has been established that there is an antarctic as well as an arctic rorqual. These discoveries recall to mind an observation of Buffon's, already more than once referred to, that every great division of the globe has animals peculiar to itself. It is true this law has not often been demonstrated in reference to the inhabitants of the ocean, although it has been alleged that the intertropical zone includes the same species throughout its whole circumference, and that as we remove from it, both northwards and southwards, each parallel has its peculiar kinds, of which the limits are terminated by the different meridians of the globe. In the present state of our knowledge, it would be going too far to affirm that none of the Cetacea plough their watery way through every clime; but Dr Scoresby decidedly states that the true Greenland whale has never been seen in European seas; and since the time that this startling statement was made, all later discoveries have greatly tended to confirm the views of the eloquent though not always accurate Buffon.

The southern rorqual but rarely approaches the coasts at the Cape, since it is stated that only two or three are observed there during the year; nor does any one think of pursuing it, since its great power and velocity make it not only difficult but dangerous of capture, and its produce by no means repays either the risk or labour.

Balænoptera Abugulich?; B. Mangidach?; B. Agamachthick?; B. Aliomoch? Pallas and Chamisso. These four are alleged species of Kamtschatka. See Lesson and Fr. Cuvier's works.

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[1] *Proceedings of the Royal Society of Edinburgh*, 1834.

Balænoptera punctulata?; B. nigra?; B. cœrulescens?; B. maculata? Rémusat, Lacép. The species just named are supposed Japanese whales, of which we certainly know little else than the names.[1] Less., Fr. Cuv.

We have now reviewed forty-nine species which appear to be established, eighteen which are probable, and thirty-three which are extremely doubtful; and having thus completed our proposed summary of the Cetaceous tribes, we shall conclude by presenting such observations on their *comparative anatomy* as may not be inconsistent with the plan of the present treatise. We shall confine ourselves to a few of the most important and peculiar parts of structure.[2]

The most striking feature in the economy of the Cetacea is, that they are Mammalia, and yet inhabitants of the ocean. We do not now refer solely to their being viviparous, whilst fish on the contrary are oviparous, though this, unquestionably, forms a very marked distinction; but, more especially, to their being warm-blooded animals, and to their discharging the all-important functions of the sanguiferous system not through branchiæ, but by means of lungs,—thus breathing like quadrupeds, whilst their appropriate element is the watery deep. Hence it is that they occupy so singular a position in the classification of the animal kingdom. Whilst they inhabit the water like fishes, and while in their mode of progression through their common element, and in some of their more obvious external characters, they seem to claim kindred with the other inhabitants of the deep, yet in every essential respect they are unequivocally marked as members, not of the last class of the Vertebratæ—that of fish, but of the first and most remote class—that of the Mammalia. Fish are produced from spawn, and after the lapse of weeks or months, emerge from their slimy beds of weed or gravel, where they had long lain neglected by their oblivious parents; but whales are brought alive into the world, and the cub is nourished for months by its mother's milk, and disports itself around her in playful affection, gambolling through the green translucent sea, like the fawn or the lambkin rejoicing in their sunny glades. Fish, again, are cold-blooded, their circulating fluid being only exposed to the water through the medium of the gills; but the whale has no gills, nor any thing resembling these organs; on the contrary, it has true lungs, in a great bony chest, into which the air is freely admitted, not indeed by the mouth, but by a peculiar apparatus to be presently explained, and through which it breathes the pure air of heaven like other Mammalia, and is thus enabled to maintain an extremely high temperature of body even in the midst of icy seas. Finally, fish never breathe, and if removed from water, and brought into air, they almost immediately expire; whereas the Cetacea, if deprived of air, and confined beneath the surface, are speedily and literally drowned.

It is this constant demand for vital air, and the consequent necessity under which they labour of coming to the surface to perform the function of *respiration*, which have procured for them the distinctive appellation of *Blowers*: and it is this same necessity which affords, in fact, the explanation of all the peculiarities of their structure. In most of the Mammalia, the inhalations succeed each other with great rapidity, and cannot be suspended for more than a few instants. In man, for example, even when at rest, they occur every three seconds, whilst the interval in the Cetacea is augmented many hundred and even thousand fold; for nearly all the whales can remain under water for a quarter of an hour or twenty minutes, and the larger genera for an hour and sometimes nearer two. But respiration is subservient mainly to the circulation of the blood; and the singular and anomalous fact just alluded to, is enough to prove that there must be some grand peculiarity in their sanguiferous system. This peculiarity has indeed for many years been recognised, but without its true use having been stated or understood. We may remark, then, that in the Cete there exists a great reservoir for arterial blood; and that when they come to respire on the surface, besides simply filling the chest with air, they likewise fill this reservoir with highly purified and arterialized blood. This reservoir consists of an innumerable congeries, *a vast plexus of great arteries*, which is lodged beneath the pleuræ, between the ribs, all round the spinal column, and even within it, as within the cranium itself. The vessels forming this plexus rise chiefly from the upper intercostal, and other great vessels near the heart; and they are found not connected by close and frequent ramifications, which anastomose freely with each other, but to a great extent they may generally be followed out and unravelled, as if they were a set of vessels twisted a thousand times upon themselves: nor do they appear to communicate directly with any veins; and hence it is inferred that after the blood from the lungs is vitiated, the pure fluid from this reservoir finds its way gradually into the general circulation, and thus for a long period maintains life. This structure was first noticed and accurately described by John Hunter.[3] Dr Barclay then described it as existing within the spinal canal of the beluga,[4] and Dr Knox more recently observed it within the cranial cavity itself of the rorqual;[5] Messrs Desmoulins and Breschet have since noticed it in France; and to these latter naturalists, we believe, belongs the merit of associating this very peculiar structure with the no less extraordinary anomaly in the respiratory function of the order, in the manner we have now attempted to explain.[6] Desmoulins likewise states that the temperature of the blood in whales is 104°, which is considerably higher than in most of the Mammalia.[7]

But while the Cetacea breathe on the surface of the water, it is equally true that they feed beneath it, and as the access of water into the lungs would be as destructive to them as to ourselves, we at once perceive that some peculiar apparatus is required whereby, when freely swallowing, water may be prevented from entering the lungs. This is effected by the peculiar structure of the *wind-pipe*. In man and the other Mammalia, the mouth and nostrils terminate posteriorly in a common pouch or bag, called the pharynx, from which both the windpipe and gullet take their origin;—the former and anterior, through an aperture called the glottis, covered by the epiglottis as a valve, which usually stands erect, but upon the passage of the food shuts down like a lid, and so leaves the posterior opening free. In the Cete, the blow-holes admit free ingress and egress of air into and from the lungs; but as the mouth is at the same time usually filled with water, a mechanism is provided to prevent the fluid from rushing with the air into the chest. The epiglottis, then, instead of being a simple and usually unshut lid, is in the Cetacea a projecting tube. In the shape of this tube there is great variety in the individual species; and as an example merely, we refer to sketches (Plate XVII., figures 3 and 4), which exhibit the larynx in the common dolphin (as shewn in the *Encyclop. Methodique*), and in the narwhal (as represented by Dr Fleming);[8] in both of which it will be observed that the rima glottidis is on the summit of a projecting cone or pyramid. This cone is received into the lower end of the blowing-*tube*, a circular aperture, surrounded with a strong sphincter muscle which includes the glottis in its grasp, thus uniting the wind-pipe and blow-tube, which cross the fauces and divide it into a kind of double vestibule. This union, however, does not appear to be fixed and permanent, so that we see no reason to conclude, as has been done, that the parts are not under the power of the will, and that the larynx cannot at pleasure be withdrawn from the blowing canal.

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[1] See *Mem. du Mus.* iv. Desmarest's *Mammalogie*, No. 808, 809, 810, 811, and Lesson's *Cetacés*.

[2] For other details the reader is again referred to the article COMPARATIVE ANATOMY of this Encyclopædia (vol. iii. p. 74), and to the works noted at page 133 of the present treatise.

[3] *Phil. Trans.* 1787.

[4] *Wern. Mem.* vol. iii.

[5] *Proceedings of Royal Society of Edinburgh*, 1834.

[6] *Mem. de l'Acad. des Sciences.*

[7] *Dict. Class. d'Hist. Nat.*, art. *Cetacés.*

[8] *Wern. Mem.* vol. i.

This is a physiological point of considerable importance, as on it depends the solution of the question now agitated regarding what forms the proper substance of the *jets d'eau* of the whale. We have already stated that the larynx enters into the lower aperture of the blowing-tube, the spiracle considerably enlarges immediately above this aperture, and proceeds upwards and forwards, through the bones and soft parts, till it reaches the summit of the head. The tube is usually divided by a septum into two canals, which in the greatest whales open by two blow-holes, whilst in all the smaller the septum ceases, and the spiracle terminates as it begins by a single aperture. It was long supposed that the liquid discharge of the spouting, was chiefly owing to the water which the Cete take in with their food, and which, if swallowed, would only incommode them. But in opposition to this, it has recently been maintained, that the proper egress of the water is the same as its ingress, and that by contracting the surrounding muscles, the throat and mouth can easily be cleared of fluid. The spiracles, moreover, have a secretion peculiar to themselves, and it is now the prevailing opinion among naturalists, that it is chiefly this secretion, together with the superfluous vapour of the lungs, which, along with the expired breath, forms the proper substance of the projected column. We venture, however, to express our doubts whether this point is either definitely or satisfactorily established. It would appear that there is an allowed difficulty arising from the great quantity of the fluid frequently expelled. This is met by the statement, that sometimes the ejected air comes in contact with the supernatant water, and raises quantities along with it. With perfect cognisance of these opinions, however, we find that M. Lesson, from much personal observation, dissented from the previously prevailing view, and, as late as 1828, maintained the old and now often-scouted opinion. He stated that from having often seen the phenomenon, and frequently within the distance of a few yards, he felt constrained to oppose the modern hypothesis. Drs Quoy and Gaimard, though they allow that sometimes no water is expelled during expiration, yet having often observed that during stormy weather the jets took place both more frequently and more abundantly, account for the fact on the supposition that, as it is then the Cetacea feed most freely, the projection of the water takes place chiefly when they are engaged in this important process. Desmoulins expresses his opinion thus: "It is not water, but mucosity, which is expelled by the blow-holes during expiration; the animal spouts water only after deglutition, or in moments of rage." This twofold view of the matter we are disposed to consider as rather feasible; and in the meanwhile we may remark, that as the mechanism is different in almost every genus, so the character of the blowing also differs greatly,—indeed to such an extent, that an experienced observer can, we believe, even at a distance determine the species at any time during day-light; the utility of which to the whalers need not be insisted upon.

The blow-holes are very extensive apertures, being not less in the larger genera than a foot in length. This is not more than sufficient when the animal is breathing upon the surface of the water; but a new train of thought is suggested when we reflect that the whale often descends to the depths of the ocean, and thus endures a pressure which can scarcely be conceived, amounting according to Dr Scoresby to 154 atmospheres, or about a ton upon every square inch. How then is this pressure to be resisted, and the water prevented from entering the lungs, and thus destroying life? This is effected mainly by *a set of valves* which act upon the same principle in all the genera, but which are varied in each by a number of contrivances equally beautiful and efficient. We shall illustrate this remark, by epitomizing a short portion of Pallas's excellent account of the apparatus in the white whale. The blow-hole opens in the most elevated part of the head, and this opening is circumscribed by a double arch. The skin is drawn towards the orifice, and forms upon it a soft papillary valve, which prevents the entrance of all foreign matters. The skin over the valve is scarcely two lines thick, but internally it envelopes a projecting body, which is about two inches thick, and is composed of a net-work of tendinous fibres hard as wood, and scarcely capable of being cut with a knife. A similar net-work of tendinous fibres, arranged in circles, forms, in this situation, the external wall of the spiracle; and two strong muscles rising from the frontal bone, and peculiar to the tube, acting on these bodies, most effectually shut them down, and so secure the canal. A similar valvular apparatus exists over the *meatus auditorius* in those species in which it is open, and not covered, as it is in most, with a strong and impenetrable membrane.

This leads to a few remarks on the *skin*, or general external covering, which is often subjected to such inconceivable pressure. The integuments, though soft and flexible like the finest velvet, are so curiously constructed as to enable them to present the most effectual resistance. We say nothing of the *epidermis*, with its mucous-oily covering, nor of the *rete mucosum*, but proceed to what are regarded as two layers, viz. the *cutis vera* and the lard or *blubber*, the former of which is represented as thick and strong, and the latter is held to correspond with the subcutaneous fat in other animals. This is the view that naturalists in general, influenced probably by analogy, have taken; it is espoused by Ray, Tyson, Pennant, Hunter, Scoresby, Cuvier, &c. But we believe that, according to this account, the great peculiarity of the structure is disregarded, and the essential character, so much desiderated, is overlooked. According to Pallas, Giesecké, and Professor Jacob, there is no distinction between the true skin and the blubber, and the whole is nothing more than modified skin. The structure, upon close examination, is found to consist throughout of an interlacement of tough fibres, crossing each other in every direction, as in the *cutis vera*, but having a somewhat more open texture, to afford room for the oil. Had the integuments consisted chiefly, as is usually stated, of a soft wrapper of common fat, though it had been double in thickness to that usually found in whales, yet it could not have so well resisted the superincumbent pressure; whereas, by its being wholly a modification of the true skin, always firm and elastic, and in this case never less than several inches, and sometimes between one and two feet thick, it operates like so much caoutchouc, and possesses such density and elasticity that the more it is pressed it resists the more.[1] Other uses of this peculiarity of the skin will readily suggest themselves. The order is warm-blooded, and yet is exposed to the keenest cold, in the most remote recesses of the frozen seas. Hence this wrapper or blanket, as it is appropriately called, being a bad conductor of caloric, will at once resist the surrounding cold, and retain the animal heat. On this account such an integument would seem to be essential; but its bulk and quantity are enormous,—sometimes weighing thirty tons. This might appear sufficient to overwhelm the animal; but, on the contrary, the fatty mass being specifically lighter than water, instead of oppressing its owner, buoys it up,—thus making it relatively lighter and more active.

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[1] For MM. Breschet and Rousset's account of the minute structure of the integuments of the whale, see *Magazine of Zoology and Botany*, vol. i. p. 181.

But we must conclude these interesting generalities by a short reference to the *brain*. It would appear that the observations made on this organ are by much too few to enable us to come to anything like general results; and in systematic writers we meet with the utmost contrariety of statement. Thus Cuvier, judging from the limited opportunities he had then enjoyed, speaks of the brain of the Cetacea generally as distinguished for its great breadth and height;[1] whilst M. Lesson, on the other hand, states that it is always very small in relation to the size of the animals.[2] Dr Scoresby states, that in a young *B. mysticetus* which weighed 11,200 lb., the brain weighed only 3 lb. 12 ounces, which is only $\frac{1}{3000}$th part of the whole animal. In a young *R. rostratus* which measured 17 feet, Mr Hunter found that the brain weighed 4 lb. 8 ounces; and M. Delalande stated that in a *Rorqual* nearly 80 feet long, the brain measured only 13 inches by 9. On the other hand, Cuvier states, from five examinations of the porpoise and dolphin, that, on the average, the brain weighed $\frac{1}{63}$d part of the whole. This statement regarding these smaller groups is corroborated by Tyson and Ray; and Tiedemann, the highest modern authority in this department, remarks: "That the brain of the dolphin is distinguished from that of monkeys by its great size and development, and next to the brain of the orang-outang, approaches nearest in this respect to that of man." From these data it would follow, that the organ is very large in the smaller groups, and very small in the larger. We insert (Plate XVII., figure 7) a sketch of Tiedemann's plate of the base of the brain in the dolphin; and may add that, considering the marked effect which the relative size of this important organ generally produces on the character of the animal, it seems desirable that every opportunity should be embraced to accumulate accurate information on the subject.

Let it be borne in mind by the rising race, that in relation to the cetaceous tribes, an enterprising naturalist of accurate habits, well versed in the recorded observations of his predecessors, and at the same time inclined to original investigation, has still before him a vast, and in several of its departments, an almost unexamined field. We here close our account of the class Mammalia. (J. W.)

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[1] *Lec. d'Anat. Comparée*, ii. 265.

[2] *Hist. Nat. des Cetacés*, 23.

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MAN, the noblest of all earthly creatures, stands related, on the one hand, through his body, to the world of matter, and on the other, through his mind, to the world of spirit. For until it can be established inductively that the modes of extension and the modes of thought are alike ultimately referable, as some have alleged, to one common substance, the laws of a sound philosophy demand the ascription of the one class of phenomena to one substance termed *matter*, and of the other class of phenomena to another substance termed *mind.* With his sensuous nature binding him fast to the present world, and his moral and religious nature raising him towards God,—at the verge of the animal kingdom most remote from its point of contact with the kingdom of organic life, yet the occupant of that other kingdom of pure intelligence where the conscience asserts its authority and dispenses its awards,—man, the only representative of the order *Bimana*, the μέροψ, the *voice-dividing*, the creature of speech, and possessor of the higher reason, stands really where he was first placed—at the head of all earthly creatures, the sole lord of the creation. From this duality of man's nature there results the two-fold division of the human sciences into *mental* and *physical.* In the former we consider man as a being capable of knowing and doing; in the latter, as a portion of organized animal matter. The mental sciences are distributed into LOGIC, METAPHYSICS, LANGUAGE, MORAL PHILOSOPHY, and THEOLOGY. In LOGIC we study the laws of thought as thought; in METAPHYSICS we either study the faculties, operations, and laws of the mind, viz., *Psychology*, or inquire into the nature of being as distinguished from phenomenon, viz., *Ontology;* in LANGUAGE we view man as capable of speech, of forming articulate sounds expressive of his thoughts and feelings; in MORAL PHILOSOPHY, or Ethics, we regard him as a responsible agent, and inquire into the nature of human duty in all its relationships; in THEOLOGY and MYTHOLOGY, again, we deal with man as a creature endowed with a religious sense—as a being capable of worship. The physical sciences which refer directly to man are ETHNOLOGY, ANATOMY, and PHYSIOLOGY. In the first we consider man as an object of natural history; in the second we investigate the structure of his body; and in the third we study the doctrine of its vital phenomena.

These branches of knowledge regard man chiefly in his normal condition. For the abnormal or diseased state of man's mind, see MENTAL DISEASES; and for the abnormal or diseased state of his body, see MEDICINE, &c.

MAN, ISLE OF, lies between N. Lat. 54. and 55., W. Long. 4. and 5.; the centre of the island being in N. Lat. 54. 16., and W. Long. 4. 30. It extends lengthwise in a N.N.E. and S.S.W. direction about 31 miles, and varies in breadth from 8 to 12 miles. Its circumference, without following the indentations of a very irregular shore, is about 75 miles; its area contains 209 square miles, or 140,447 statute acres, 30,000 of which are mountains and commons. The island is situate nearly mid-channel in the Irish Sea, about equidistant from England, Scotland, and Ireland.

The outline and aspect of the island is thus described by the Rev. J. G. Cumming of Lichfield:—"The *northern* view is a narrow track of almost level land (which is an almost plane area of 50 square miles), surrounded by an abrupt pile of mountains, rent in chasms, forming the lovely glens of Ravensdale, Sulby Glen, Glen Aldyn, and Ballure. The *western* view is that of an extended pile of mountains, descending rapidly to the sea on the nearer side, distinctly precipitous at the south-western extremity, intersected at right angles by the two valleys of Port Erin and Peel. The *southern* view is that of a gradual slope from the sea-level to the highest points, without any distinct valleys, but occupied by towns, villages, villas, cottages, corn fields, and pastures. The *eastern* view (as presented on approaching from Liverpool) is that of a succession of bold cliffs and headlands, backed at a distance of 7 or 8 miles by mountains, ranging from 1500 to 2000 feet high, between which and the cliffs the slope is generally easy, and clothed with verdure. From the intersection of the Douglas valley at the centre, and the Straits of Kitterland at its southern extremity, separating the Calf Isle from the mainland, it appears as if divided into three distinct portions. Another peculiarity is, that as the vessel approaches the island, it appears *suddenly* lengthened to the extent of 6 miles at its northern extremity. This is caused by the low, level tract of land extending from the foot of the mountain chain to the Point of Ayre; and being only a few feet above the sea-level, it is the last portion to appear and the first to disappear, according as the spectator may approach or recede."

The mountain chain, which forms the most prominent feature on its surface, intersects the island in an oblique direction, and extends from Marughold Head to the Calf Islet, comprising within its range Sneafield, North and South Barrule, Bein-y-Phot, Greebah, and many others. The highest summits are Sneafield and North Barrule, the former being 2036, and the latter 1854 feet above the level of the sea. The sides of the mountains are clothed with turbary, moss, and heath. The whole chain, beginning with North Barrule, consists of clay schist (lower silurian), which is also the prevailing formation in South Barrule (1592 feet), the latter being varied on the eastern side with large masses of granite containing silvery mica, red and white felspar, and grey quartz. Greebah is 1600 feet above the sea-level, and is rugged and precipitous, especially on its southern side, towards the Douglas and Peel road. Bein-y-Phot (1784 feet) is marshy, and even in summer the ascent is tedious. The other mountains of lesser note are,—Slieau-ny-Fraughane (1598 feet), Irey-ny-Lhaa (1445 feet), Slieau-ny-Carnaane (1449 feet), Slieu-Dhoo (1139 feet), Slieau-Whallin (1068 feet), and Sartel, Slieau-Hearn, Slieau-Chiarn, &c. From Sneafield, which rises in the southern extremity of Ayre, in clear weather, one can descry the mountains of Cumberland and Lancashire in England, of Carnarvon and Anglesea in Wales, of Arklow and Morne in Ireland, and of Galloway and Dumfriesshire in Scotland.

The rivers of the island, though numerous, are all small in size. The Sulby, the largest, rises in the mountain group around Sneafield, and, after running 9 miles, discharges itself into the sea at Ramsey. The Neb, or Great River, has one portion of its tributary streams on South Baroole, and after being joined at Slieau-Aalin by a branch issuing from the western side of the mountains of Kirk German and Kirk Michael, joins the Irish Sea at Peel. The Silverburn, or Castletown River, has also two branches, the principal of which rises in the S. side of South Barrule, and, uniting with the other a little below Athollbridge, terminates its course in Castletown Bay. The Dhu, or Black River, takes its rise in the W. side of Mount Garrahan, and at about a mile from Douglas it receives the waters of the Glass, or Grey River, which rises in the mountain group of which Bein-y-Phot is the centre. The Laxey River descends from the eastern declivity of Sneafield, and terminates its course in Laxey Bay.

The following remarks on the natural history of the island were contributed by the late Professor Edward Forbes to *Kerruish's Guide to the Isle of Man:—*

"In common with Ireland, this island is exempt from venomous reptiles and toads, as neither serpents nor toads are found in it; but frogs are abundant, though they are popularly believed to have been imported, an idea for which there is no foundation. *Lacerta stirpium* (sand lizard), is common in the N.; and *Lacerta agilis* (common lizard), abounds in old hedges and dry banks in every part of the island. *Triton palustris* (warty eft), and *Triton punctatus*, (common eft), are by no means rare in their different habitats everywhere. Several of the more common of the four-footed English annoyances are absent, such as foxes, badgers, and otters. It is said that deer formerly inhabited the mountains, but they, like their great prototype, the fossil elk, have long since passed away. The only remarkable quadruped peculiar to the island, and of which it can boast, is the tailless cat, an accidental variety of the common species *Felis catus*, frequently showing no traces of caudal vertebra, and others a merely rudimental substitute for it. Of game birds, a few of the partridge and quail remain, but grouse is no longer to be found. Snipes are abundant. That rare bird the Manx puffin (*Procellaria anglorum*), formerly an inhabitant of the Calf, is now rarely found there. Of the rarer British land birds, the red-legged crow is common; the king-fisher scarce; and the hoopoe, the goatsucker, the shrike, the cross-bill, and the roller, have been killed on the island. Of sea-birds there is great variety. Many rare fishes, as might be expected, are found in the neighbouring sea. The entomology of the island is not attractive, though a few of the rarer coleoptera may be found on the sandy district of the N. Many scarce shell-fish abound on the coast, and on the banks which surround the island. It is not remarkably rich in plants, and probably does not contain more than five hundred species of the flowering kinds. Nevertheless, among them are several scarce species."

The following brief summary of the geology of the island was also furnished to the same work by the Rev. J. G. Cumming:—

"It is only of late years that the geology of the Isle of Man has attracted attention, and yet it is full of interest. The very large development of mineral resources, especially in the mining districts of Foxdale and Laxey; the value also of the quarries of granite, limestone, flagstone, ironstone, and marble;—gives a particular importance to the determination of the geological age of the strata of which the island is composed. Fire, water, ice, have each in turn played their part and exerted their distinctive power in fashioning and moulding this little gem of the ocean into its present shape. The rounded form of the mountain summits which must strike every visitor when he first catches sight of Mona, is due to the fact, that, having been in vast bygone ages elevated by volcanic agency from the depths of ocean, they were at a subsequent period submerged into a sea of an arctic character; and standing in the midst of a current charged with icefloes and icebergs, were ground down, rounded off, and polished. And yet that a much milder climate here also once prevailed, we have evidence in the carboniferous deposits charged with remains of nautili, corals, and tree ferns, the present denizens of seas and lands mostly within the tropics. The rocks of the Isle of Man belong to the palæozoic and to the pleistocene periods. All rocks of the mesozoic and kainozoic periods up to the pliocene strata inclusive, are wanting; and even the uppermost palæozoic beds, viz., the coal measures and the permian sandstones and limestones, are not to be found. The lower palæozoic series is by far the most largely developed, forming the main body of the island. From the Calf of Man to Maughold Head we have a series of schists, forming a mountain range in a rather irregular curved line, whose general direction is from S.W. to N.E., which may be regarded also as the general line of strike. In the almost total absence, as far as yet examined, of any characteristic fossils in these beds, it may be convenient to regard them as lower silurian. They have been disturbed and elevated by the intrusion of granites and porphyritic greenstones. The greenstones may be observed sometimes intrusive, at others apparently imbedded at various points along the mountain ridge from the Sound of the Calf to Maughold Head, more especially at Brada Head, at Rock Mount, near the Tynwald Hill, and at the head of Craig Willis, near the church of St John the Evangelist. They may also be traced along the coast from Langness to Douglas. The granite rises in an enormous dome on the south-eastern side of South Barrule, near the mining district of Foxdale. It also appears at the Dhun River to the N.E. of the Laxey Mines. No doubt the value of these mining districts is greatly enhanced thereby. It has always been found that the metalliferous veins increase in richness as they approach the granitic nuclei. At Foxdale the lead ore in contact with the granite, and in the granite, has yielded more than one hundred ounces of silver to the ton. Where the schists repose upon the granite bosses they are highly metamorphic, and pass by various stages from clay-schist through grauwacke-schist, and mica-schist with garnets, into gneissose-schist and gneiss. No true slate has yet been discovered on the island. The flagstone used for slate seems to have been split in lines of bedding and not of cleavage. At Spanish Head masses of a deep blue clay-schist, slightly clastic, are procured and used largely for lintels. The old red sandstone and conglomerate occurs on the north-western side of the island, at Peel, and also on the south-eastern in the neighbourhood of Castletown, where it crops out around the eastern and northern edge of a basin-shaped depression, occupied by the limestones and shales of the carboniferous era. It rests unconformably upon the upturned edges of the schists, and passes upwards by almost insensible degrees into the beds of limestone. We notice a gradual abstraction of the red matrix around the quartz pebbles of the conglomerate, and a substitution of a grey calcareous matrix instead, with a few of the lower limestone fossils imbedded; ultimately the quartz pebbles die out, and we reach the regular dark limestone beds. The carboniferous series of the Isle of Man may be subdivided into lower dark limestones and shales, comparable to the carboniferous beds of Hook Point in Ireland, and those near Dent and Ulverstone in England; then the upper light-coloured and highly fossiliferous limestones of Poolvash, the equivalents of the scar limestone of Yorkshire and Bolland; and thirdly, the Posidonia schist of Poolvash, the nearest approach in the Isle of Man to the coal measures. This last division contains the so-called Manx black marble, and has been largely wrought into chimney-pieces. It forms the steps of St Paul's Cathedral, London, which were presented by the Venerable Bishop Thomas Wilson. It contains abundantly the peculiar fossil *Posidonia* (whence the name), and some traces of *Calamites*, *Lepidodendra*, and tree ferns. All these beds are greatly intersected and broken up by trap dykes between Langness and Poolvash, the phenomena connected with which may be best observed between the Stack of Scarlett (itself a basaltic pile) and the black marble quarries at Poolvash, and thence along the shore to Kentraugh. The Posidonia schist is actually intercalated with beds of trappean ash; this ash also containing the fossil remains of the animals living in the neighbouring sea at the time when the volcanic eruption took place. A great fault, running from Perwick Bay, Near Port St Mary, in the direction for 5 miles of the granitic boss on South Barrule, cuts off all the beds of the old red sandstone and the carboniferous limestone, the up-cast being on the N.W. side. The whole country on both sides of this fault has subsequently been planed down to one level, and then overspread by the boulder-clay and sands of the *pleistocene* series. The *pleistocene* series of the island consists of boulder-clay, drift-gravel, and sands, which are largely spread out over all the other rocks, and reach far up the mountain-sides, the boulders being found even on the summits of some of the loftiest southern mountains. A large tract of nearly 50 square miles, in the north of the island, is wholly occupied by these beds, for the most part forming a large plain, in which are basin-shaped depressions, covered with beds of peat, but rising also between Point Cranstal, Blue Head, and Jurby Point, to hills upwards of 300 feet in height. In former times (as appears by old maps and records) lakes existed in the depressions in the north of the island, which have since been drained. In still more ancient lakes shell-marl was deposited, and in them we find the remains of the *Megaceros Hibernicus*, or great fossil elk, a fine specimen of which, discovered many years since near Ballaugh, was presented to the Edinburgh Museum by the Duke of Athol. As this was the first almost entire skeleton of the animal discovered and described, it ought rather to have been called Manx than Irish elk. There is no doubt but that the *pleistocene* series occupied at one time the whole bed of the Irish Sea, and united the Isle of Man with the surrounding countries. The rocks immediately under the boulder-clay, where they can be discovered, are distinctly grooved, furrowed, and scratched in a direction generally parallel to the mountain chain; and the boulders consist chiefly of masses of the immediately subjacent rock, themselves scratched and grooved: they have every appearance of having been pushed along in an icy stream. The true boulder clay is very deficient in fossils, and such as occur are, as might be expected, in a very broken and comminuted condition. In hollows in the boulder-clay we find masses of sand and gravel, where the fossils are in a more perfect condition, and present very much of an arctic or sub-arctic character. The drift gravel which overlies the boulder-clay seems to consist of its re-formed material, rounded and worn. If we consider the boulder-clay to have been deposited (as is most probable) during a period of general subsidence of this area, then the drift-gravel marks the period of re-elevation. At certain periods, both of the depression and re-elevation, the present Isle of Man would have exhibited the appearance of a cluster of five or six islands, with strong ice-charged currents flowing between them. The drift-gravel contains pebbles of foreign rock, chiefly Scotch, with some chalk flints, probably derived from the north of Ireland. The most remarkable phenomenon of the boulder-clay which can be noticed, is the occurrence of boulders of undoubted South Barrule granite which have been raised several hundred feet, within the space of 2 miles from the parent source, and perched on the tops of South Barrule, Cronk-na-Irey-Lhaa, and other southern mountains, as well as carried over the ridge in great abundance to the western side of the island. It is not unlikely that being frozen into shore ice, as the mountains were gradually submerged they were stranded higher and higher each succeeding year, and the highest of them will mark the extent to which at least that submergence took place."

The principal minerals are lead and copper ore. The Laxey Mines, near the banks of the Laxey River, produce ores of lead and copper, with much blende (sulphuret of zinc). At Foxdale, between Castletown and St John's, the Isle of Man Mining Company carry on operations to a considerable extent. Lead ore and sulphuret of copper are also found and wrought by the South Manx Mining Company at Brada Head. The mines are rented from the Queen, as lady of the manor, the lessees paying one-tenth part of the produce. The quantities of lead ore, lead, and silver produced in 1852 are as follow:—

	Tons lead ore.	Tons lead.
Isle of Man Mining Company..........	1600	1224
Laxey Mining Company.................	800	600
South Manx Mining Company.........	15	11¼

The average yield of silver from each ton of lead ore is 20 oz., and the produce for the year above named was 36,700 oz.; the value of which, at 4s. 2d. per ounce, was L.7646.

Besides the mines proper, the lime and marble quarries of the S. are worked to a considerable extent; the lime being very valuable, not only for building purposes, but also for agriculture. There is a valuable granite quarry in the region of Foxdale. Rotten-stone and ochre are obtained in the S., near Ballasalla, and a considerable foreign trade is carried on in them. The white spar raised in the Laxey lead mines is valuable.

The climate of the island is noted not only for its mildness but also for its general equality. The mean temperature of the year is 49°·84; of summer, 58°·98; of winter, 41°·57; of July it is 60°·33, and of January 40°·52;—giving the difference between the hottest and the coldest months as 19°·81; between summer and winter as 17°·41.

Before the time of the revestment of the sovereignty of Man in the British Crown, in 1765, agriculture was almost entirely neglected. The herring fishery formed the chief occupation of the peasantry, whilst the women and children cultivated just as much land as would supply the wants of the family and pay the lord's rent.

For the present highly improved state of agriculture, the island has been mostly indebted to the enterprise of English and Scotch farmers, who set a good example in the cultivation of apparently barren land. The dormant energies of the people being thus called forth, they, in many instances, have not been slow to imitate their instructors, and have been amply rewarded with success. Generally speaking, land in a good situation, well cultivated, will give a return in oats of 36 to 45 bushels per acre, barley in the same proportion, and wheat from 25 to 30. In the neighbourhood of the towns, land is let from L.4 to L.5 per acre. The mode of agriculture comprises a succession of crops in the following order:—First, grain crop; second, green crop or summer fallow; third, clover and hay; fourth and fifth, pasture. The proportions of grain sown are,—oats, one-half; wheat, one-fourth; barley one-fourth. Previous to 1845 potatoes were cultivated to a very great extent, and constituted a considerable item of export. Turnips, for which the soil appears to be very favourable, are produced in great quantities; and, from an improved method of cultivation, are allowed, even by the Yorkshire farmers, to be superior to those grown in their own favoured county. Most of the artificial grasses thrive well; the white and red clover, and the common grasses, yield generally good crops, and large quantities of hay are stacked in most of the agricultural districts. The commons, or uncultivated lands, are estimated to form about one-third of the island, including the whole of the mountain-chain. Upon these wastes horses, cattle, and sheep are turned to graze, particularly by the upland farmers. The principal food of these animals during the winter season is the evergreen furze. The native breed of horses is of a small kind, but hardy, useful, and patient of labour, being somewhat similar to those of North Wales. Horned cattle are numerous, but the native breed, being much neglected, have degenerated. Lately, however, the farmers have been improving the breed by the importation of Ayrshire and short-horned cattle. The native breed of sheep is very small, but hardy; their wool is not very long, nor of the finest quality. In the low lands a larger breed has been introduced. There is also a peculiar breed, which is now rapidly disappearing, called, from its mouse-brown colour, the *Loaghtyn*, or *Lugh-doan*. Pigs are bred in considerable numbers.

With respect to the size of farms, the largest portion of cultivated land is held by yeomen, farming from 10 to 150 acres, their own property. In the vicinity of the towns the occupations are generally small. Rent varies from 10s. to L.5 per acre, depending upon the quality of the soil, the means of communication with the town, &c. Though the north possesses an excellent soil, yet the convenience of lime and sea-weed is wholly in favour of the south. Since the abolition of the corn laws in England, little more grain is grown than will suffice for home consumption. Large numbers of cattle, however, are bred for exportation, and are conveyed by steamers to England.

The manufactures and trade of the island are limited, the want of coals being assigned as the principal reason. The staple article of commerce is the products of the fishery; and perhaps the next to that is the mineral treasure.

The peculiar fiscal privileges of the island, as also its influx of visitors, and the large circulation of money they induce, contribute materially to its prosperity and progress; to which may be added the frequent retirement to its shores of opulent residents from the sister isles. Spirited attempts to promote manufactures have, however, been made, and there are now several mills for the manufacture of canvas, woollen cloths, nets, ropes, twine, &c. There are also breweries, tanneries, and soap factories; iron foundries, gas and water companies, &c. Apart from the herring fleet, consisting of about 400 smacks or luggers, the island has a number of small coasting vessels, which are chiefly used for the exportation of grain, ore, &c., and the importation of coals. The latter class of vessels are being gradually superseded by steamers, which ply regularly between Liverpool and Douglas, Ramsey, and Castletown.

The roads of the island are excellent, and are maintained —1*st*, by a system of licenses on innkeepers, grocers, hawkers, &c.; 2*d*, by an impost on carts, carriages, and dogs; 3*d*, by a prescriptive labour duty on housekeepers; and, 4*th*, by a like duty on the quarterlands. The annual fund from all these sources is between L.4000 and L.5000, and it is most ample for the support of all the roads, which are under the management of a highway committee, a surveyor-general, and parochial overseers. Although surveys were made by two companies during the railway mania of 1845, the proposed railway lines for the connection of the four towns of the island were never commenced. Surveys have again been made, with a view to the opening of a railway communication between Douglas and Peel.

The civil government of the Isle of Man is vested in three estates—the Queen in Council, the Governor and Council, and the House of Keys. These last two estates together constitute a court of Tynwald; but the concurrence of the three is essential to every legislative enactment. Acts of the British legislature do not affect the island except it be therein specially included.

The Governor is captain-general of all the troops on the island, and also of the constabulary force. He presides in the council, in all courts of Tynwald or legislature, in all staff of government courts, courts of general gaol delivery, and is *ex officio* sole judge in Chancery and Exchequer courts.

The Council, or staff of government, consists of the lord bishop of the diocese, the attorney-general, the receiver-general, the two *deemsters*, the clerk of the rolls, the water-bailiff, the archdeacon, and the vicar-general, who are also *ex officio* justices of the peace for the island. One or both of the deemsters, the clerk of the rolls, and the water-bailiff, generally sit as assessors in the courts in which the governor presides. The act of the governor and three of his temporal officers is considered a valid act of the governor and council.

The House of Keys consists of twenty-four representatives, who are not elected by suffrage, but are selected by their own body, vacancies being filled up by the House presenting to the governor "two of the eldest and worthiest men of all the Land of Mann," one of whom he nominates, who then takes his seat for life. To them an appeal may be made against verdicts of juries at common law in all cases; and against their decision there is no appeal but to the Queen in Council.

In matters of property the Court of Chancery has the most extensive jurisdiction of any in the island, and is both a court of law and equity. The governor presides, and is assisted by the clerk of the rolls, the deemsters, and the water-bailiff. Like the English Court of Chancery, the proceedings are conducted without the intervention of a jury.

The Exchequer Court takes cognisance of all matters connected with the revenue: proceedings are here carried on for the recovery of all penalties and forfeitures due to the crown, incurred by frauds upon the customs. It passes sentence upon all convicted criminals, and also decides the validity of all titles. This court also determines the right of tithe, which, previously to the act of 1777, was cognisable only by the ecclesiastical courts.

The Common Law Courts for the southern division are held at Castle Rushen, and for the northern division at Ramsey, once in three months. These take cognisance of all actions, real, personal, and mixed, and of all civil matters that require to be determined by a jury. The juries consist of six men, against whose verdict an appeal can be made, in the first instance, to the House of Keys, who possess the high power of affirming, reserving, or altering a verdict at common law.

The Courts of General Gaol Delivery are held twice a-year at Castletown, for the trial of prisoners indicted for criminal offences: the governor presides, attended by the deemsters and the clerk of the rolls. The execution of the sentence of this court in cases of treason, murder, or other capital offences, is never carried into effect until the royal pleasure can be ascertained.

The Deemsters' Courts are of great antiquity. They are held weekly, alternately at Douglas and Castletown, by the deemster for the southern division; and at Ramsey and Peel, or Kirk Michael, by the deemster for the northern division. The judge in this court, by his sole authority, determines in cases of trespass, slander, assault, battery, debts, and contracts; but an appeal can be made against his judgment to the staff of government. The deemsters possess very extensive jurisdiction and high authority; they are the chief justices and the ancient popular magistrates. Their authority is not limited by law to their own divisions, but they have concurrent jurisdiction over the island. They are appointed by the crown, each having a salary of L.800 per annum. On the deemsters every department of the legislature and government depends for advice and direction in all difficult points of law. They take cognisance in a summary manner of all breaches of the peace, and can hold courts instantly on all criminal informations.

The herring fishery, and the boats employed in it, are placed under the charge of the water-bailiff, and he usually holds a court once a-week, to redress grievances, and enforce the regulations of the fishery. He appoints, with a small salary, two intelligent fishermen, who are called admirals, to assist in preserving order. The water-bailiff has also civil jurisdiction in questions of salvage, and takes cognisance of suits in maritime matters, similar to the admiralty courts in England. Against his judgment an appeal can be made to the staff of government.

The High Bailiff's Courts are held weekly in Douglas, Castletown, Ramsey, and Peel, for the recovery of debts under forty shillings.

The Ecclesiastical Courts are,—the consistorial court, in which the bishop, or his vicar-general, or registrar presides, taking cognisance of all matters relating to the probate of wills, granting letters of administration, alimony, church assessments, &c.; and the vicar-general's court, which takes cognisance of all offences against religion, good morals, and the interest of the church, and of all cases not cognisable by the common law courts. The chapter or circuit courts are held for regulating all matters connected with the see, and the general affairs of the diocese.

The magistrates hold regular courts in Douglas fortnightly, and monthly in each of the other towns, for the summary trial of offences for breach of the peace and misdemeanours. These gentlemen are appointed by commission under the Great Seal of England, but their powers are regulated by an insular act of Tynwald. The members of the council and the four high bailiffs are also *ex officio* magistrates, and their clerk is a member of the bar, appointed also by the crown.

A coroner, anciently termed a *moar*, is appointed by the governor to each of the six sheadings or districts of the island, at the Tynwald Court, on the 5th July, annually. He unites in his office the powers possessed by an English coroner, constable, and sheriff's officer. He is both a ministerial officer and a conservator of the peace, and, according to ancient statute, holds his office for one year only.

The laws of the island still retain much of their ancient peculiarity of character, though modified by occasional acts of Tynwald, and rendered in some respects more in unison with those of England. By acts of Tynwald, passed in 1777 and 1813, the criminal code was greatly altered and amended.

The general tenure is a customary freehold devolving from each possessor to his next heir-at-law. The right of primogeniture extends to females as well as males. The interest of a widow or widower, being the first wife or husband of a person deceased, is a life estate in one-half of the lands which have descended hereditarily, and is forfeited by a second marriage; a second husband or second wife is only entitled to a life interest in one quarter. Of the land purchased by the husband, the wife surviving him is entitled to an absolute moiety. By a statute of the year 1777, proprietors of lands are empowered "to grant leases for any term not exceeding twenty-one years in possession."

The annexed Table exhibits the Population of each Parish, and its Relative Increase from 1726 *to* 1851.

Sheadings.	Parishes and Towns.	POPULATION.				
		1726.	1757.	1821.	1841.	1851.
Rushen..	P. Malew	890	1,466	2,649	3,085	3,232
	T. CASTLETOWN...	785	915	2,036	2,283	2,501
	P. Arborey.....	661	1 785	1,455	1,615	1,593
	P. Rushen......	813	,007	2,568	3,079	3,262
Middle...	P. Santon......	376	507	800	769	714
	P. Braddan ...	780	1,121	1,754	2,122	2,407
	T. DOUGLAS...	810	1,814	6,054	8,647	9,653
	P. Onchan......	370	434	1,457	2,589	3,478
Glenfaba	P. Marown.....	499	658	1,201	1,318	1,363
	P. Germain ...	510	925	1,849	1,896	2,168
	T. PEEL........	475	805	1,909	2,133	2,329
	P. Patrick......	745	954	2,031	2,768	2,923
Garff.....	P. Lonan......	547	869	1,846	2,230	2,605
	P. Maughold...	529	759	1,514	1,585	1,764
	T. RAMSEY ...	460	882	1,523	2,104	2,660
Ayre.....	P. Lezayre....	1,309	1,481	2,209	2,323	2,455
	P. Bride........	612	629	1,001	1,153	1,053
	P. Andreas....	967	1,057	2,229	2,332	2,165
Michael.	P. Jurby.......	483	467	1,108	1,068	983
	P. Ballaugh...	806	773	1,467	1,516	1,392
	P. Michael.....	643	1,826	1,427	1,376	1,416
	Total......	14,070	20,134	40,087	48,001	52,116

The number of houses in 1841 was 8393, and in 1851, 9108; of the latter number 8611 were inhabited.

Language.—The Manx language is a sub-dialect of the Gaelic or ancient Celtic, and it has great affinity to the Erse or ancient Irish language. The natives of the south and west of Ireland, of the Highlands of Scotland, and of the Isle of Man, have but little difficulty in understanding and conversing with each other. This, however, applies only to the pronunciation, for their differences in orthography are such as to perplex even the most learned linguists. The Manx is now only spoken in the north-western parishes, and at a few localities along the western coast, though, with few exceptions, the natives are able to converse in the English language. The services in the parish churches are given alternately in the Manx and English languages, though the Manx is not taught in any of the parochial schools; and it is very probable that in the course of the next generation it will become utterly extinct.

All religious sects are tolerated in Man; but its establishment is connected with the Church of England. It is a diocese in the province of York; but its bishop has not a seat in the House of Peers. His double title of Sodor and Man has its origin in one of those ages so fertile in materials for antiquarian guesswork. Some will have it that Sodor is derived from *Sotor*, the ancient name of a village in Iona; others allege that it is a contraction of the Danish word *Sudoroe*, significant of the Hebrides, which the Scandinavian rovers approached generally from the N., and which are said to have been at one time under the spiritual jurisdiction of the Manx bishops; whilst some, with equal propriety, maintain that it was applicable only to a little island off Peel, and formerly called Sodor, on which a lordly castle once stood, containing the cathedral in which many of its bishops were consecrated, and the cemetery where the dust of most of the wise, and the brave, and the noble of the land was deposited. The bishop is assisted in ecclesiastical matters by an archdeacon, a vicar-general, a registrar, and a sumnar-general. The livings of the clergy arise chiefly from tithes; the patronage, from the bishopric downwards, with the exception of three in the gift of the diocesan, is vested in the Crown. The revenue of the church of Man is a good one, and amply sufficient to maintain all its clergy comfortably, were it only a little more equitably divided. In no part of the world is religious toleration better established than in this island,—not even Britain, with all her boasted religious liberty, excepted,—no license being required, either for the preacher or the place in which he ministers, and liberty of conscience is enjoyed by all. Man is well supplied with the appliances of education. Besides King William's College, there are academies of the very highest class. Its parochial schools have likewise considerably improved during the last few years.

Previous to the Act of Revestment in 1765, the commerce of the island consisted principally of the importing and exporting of contraband goods, the average returns of which exceeded half a million sterling per annum. During that period the island was the grand refuge and storehouse for smugglers, who, as occasion offered, shipped their goods to England, Scotland, and Ireland, to the great injury of the British revenue; the loss to which was then estimated at L.300,000 per annum. After this period the customs of the isle became vested in the British crown, and were placed under the control of a receiver-general, and subsequently, by an act (50th Geo. III.) the regulation and management were transferred to the commissioners of customs in England, which have since remained under their superintendence; and this little island, instead of being a burden to the mother country, now remits about L.30,000 annually to the consolidated fund, after all expenses are deducted.

By the act 7th and 8th Vict., chap. xliii., passed 19th July 1844, commonly called "The Fiscal Bill," the entire revenue of the island is regulated, and has been relieved from many vexatious restrictions.

In 1853–54 several fiscal changes were made by the Lords of the Treasury. Previous to this period British gin and whisky of any description were absolutely prohibited, but they are now admitted, entitled to an inland revenue drawback of 7½d per gallon. Brandy, Geneva or Hollands, and rum, were imported under special license in the undermentioned restricted quantities per annum; and the following table will show the difference between the old and new tariffs:—

	Annual Limitation.	Former Duty.		Present Duty.		
	Gallons.	s.	d.	s.	d.	
Brandy	20,000	4	6	6	0	Without limit or restriction as to quantity imported.
Geneva	20,000	2	6	6	0	
Rum	70,000	1	6	3	8	
Liqueurs	50	10	0	10	0	
Eau-de-Cologne	50	10	0	10	0	
Tobacco	55,000 lb.	1	6	1	6	
Do. manufactured		1	6	4	9	
Cigars	5,000 ,,	3	0	4	9	

To counterbalance the above increase of duties on the luxuries, the following reductions were made on the necessaries of life:—

	Former Duty.	Present reduced Duty.
Tea	1s. per lb.	6d. per lb.
Sugar (Muscovado	1s. 6d. per cwt.	1s. per cwt.
... (Refined)	9s. per cwt.	3s. per cwt.

History.

The little that is known of the early history of the Isle of Man is derived from tradition, from the annals of the surrounding countries, from the Norse and Erse Sagas, and from a record by the monks of Rushen Abbey called the *Chronicon Manniæ*.

The earliest personage mentioned by tradition and history is Mannanan-Beg-Mac-y-Lheirr, from whom the Manx believe the island to have derived its name. He is thus described in the Statute-Book of the island:—"Mannanan-Beg-Mac-y-Lheirr, the first person who held Man, was the ruler thereof, and after whom the land was named, reigned many years, and was a Paynim—he kept the land *under mist* by his necromancy. If he dreaded an enemy, he would cause one man to seem as a hundred, and that by art-magic." He was reputed to be a son of a king of Ulster, and by others a son of Alladius; but both ideas are irreconcilable with history. He appears to be identical with Mainus, the son of Fergus I. of Scotland, who ascended the throne of Scotland 290 B.C. The ancient English historian Nennius, and also Camden, state that Brule or Brude, a Scot, governed the Isle of Man in the reigns of Emperors Aurelius and Honorius, A.D. 395. In 517 Maelgwyn, King of North Wales, who proved a formidable foe to the Saxons in England and the Scots in Man, expelled the Scots, and annexed the island to his Welsh dominions. For this exploit Maelgwyn, who was nephew to the renowned King Arthur, was created a Knight of the Round Table. He was succeeded by his son Rhun-ap-Maelgwyn in 560, from whom in 581 the island was reconquered by Aydun M'Gabhran, King of Scotland, who appointed his sister's son Brennus his viceroy, with the title of "Thane of Man." The Isle of Man appears to have been under the Scotch vice-royalty until about the year 611, when Cadwallon, the Welsh king, appears to have recovered it from the Scots, and to have retained possession of it until 630. Having invaded Northumberland, he was defeated, with immense loss, at the battle of Weddington, by Edwin, the king of the Saxon province of Deira, who, following up his victory, subjugated the isles of Anglesey and Man. Some years afterwards, Cadwallon, obtaining aid from France and Scotland, reconquered the territory which had been overrun by Edwin. Towards the end of the ninth century Harold Harfagra, the son of Halfdan Ivart the Black, the most powerful of the Norse Vikingr, overran and devastated with indiscriminate slaughter the whole of the Western Isles and Man. He appointed as lieutenant of Man and the Isles the jarl Ketil Flatnefr, or Flatnose, who afterwards threw off his allegiance and assumed the sovereignty. He soon afterwards died, and was succeeded by his sons Helgi and Thorstein the Red, the last of whom was expelled in 894. The next king, Mal, was succeeded by his nephew Amlaf or Olave, whose reign was of short duration. In the meantime Harold Harfagra had resolved on uniting the petty kingdoms of Norway into one sovereignty, and after many years of warfare, he effectually succeeded in his object. There is reason to suppose that this act, and his subsequent tyranny, induced the simultaneous emigration of Rollo and his companions to Normandy, of Ingolf to Iceland, and of Orry to the Isle of Man, where they all established independent kingdoms.

After subjugating most of the Western Isles, King Orry arrived in Man, and succeeded in establishing his sway over the island. He was a wise and politic prince, and during his reign the Manx enjoyed undisturbed tranquillity. To him the Manx are indebted for a legislative government. He first divided the island into six sheadings, each of which sent its representatives to the court at Tynwald Hill which was formed in his reign. His descendants continued to rule over Man till 1077, when Godred IV. (Crovan), at the head of a horde of Norwegians, routed the islanders and slew their king, Fingal II. He established himself in the southern district of the island; the remainder he granted to the inhabitants, on the absolute condition of their holding it under him as lord of the whole.

On the death of Godred in 1093, Magnus Barefoot succeeded in obtaining possession of Man, over which he placed the Norwegian jarl Octtar as governor. The inhabitants of the southern district becoming displeased with Octtar, elected Macmarus in his place; a battle in consequence ensued at Santwart (or Sainthill), in the parish of Jurby, and victory was inclining to the party of Macmarus, when the women of the north, rushing to the scene of action, totally changed the issue of the fight, although not till both leaders were slain.

On the death of Magnus, the right of Godred Crovan's line to the kingdom of the Isles was recognised, and Lagman, the son of that conqueror, succeeded to the government; but, from his excessive tyranny, he became detestable to his subjects. He at length abdicated the throne, and undertook a pilgrimage to Palestine, whence he never returned. Olave II. (surnamed Kleining, or the Dwarf), the only surviving son of Godred IV., being then a minor, a regent was appointed, who, by his acts of tyranny and oppression, rendered himself so obnoxious to the people, that he was expelled from the kingdom in the third year of his government. Olave II., who had attained his majority, ascended the throne of his father, and prudently secured peace to his dominions by entering into alliance with the kings of England and Ireland, and by contracting a marriage with Alfrida, daughter of Fergus, lord of Galloway, and grand-daughter of Henry I. of England. His previously quiet reign was disturbed by the pretensions of three natural sons of his brother Harold, by one of whom he was treacherously slain at a conference in 1154. The triumph of the three rebellious nephews was not of long continuance. Godred V. (the Black), Olave's only legitimate son, was recalled from Norway, where he was receiving his education; the whole of the Isles submitted to his authority; and the sons of Harold were delivered to condign punishment. Several attempts were made during his reign to obtain possession of the island, one of which by Somerled, surnamed the Surly, Thane of Argyle, was successful, and Godred had to take refuge in Norway, where he remained till the death of the usurper, on which he regained possession of his throne. His death took place in 1187, in the thirty-third year of his reign. Olave III., his only legitimate son, being then a minor, Reginald, another son, was appointed to the government during his minority. The latter endeavoured to secure to himself the throne by doing homage to John of England, and afterwards by acknowledging the superiority of the pope; but all these efforts were unavailing, and a series of struggles was the consequence, till at length Reginald was slain in a sanguinary engagement in 1229. In A.D. 1237 Olave died in Peel Castle, leaving three sons,—Harold, Reginald, and Magnus; and was succeeded by his son Harold II., who, with his queen and a numerous retinue of nobility, in 1248, were drowned on their return from Norway, where they had been celebrating his marriage with Cecilia, daughter of Hakon, the Norwegian king. His brother Reginald III. assumed the government, and was afterwards slain, with all his party, by the Knight Ivar, a natural son of Godred V. (and brother of the illegitimate Reginald II. the usurper), in 1249. On the death of Reginald III., who left only an infant daughter, his brother Magnus was chosen king. According to usual custom, he went over to Norway, and after two years' attendance at that court, was declared King of the Isles, and had the title confirmed to himself and his heirs. In 1250 John, King of England, landed with an army at Ronaldsway, and proclaimed himself King of Man and the Isles; but his army was defeated and compelled to retreat.

From this time the power of the Norwegian kings began to decline, and that of the Scottish sovereigns to revive. Magnus, threatened by an invasion, did homage to Alexander III. of Scotland, and received from him a charter, by which he held the island from the crown of Scotland. He died in 1265, without issue. In the meantime, Magnus VI. of Norway, as the legitimate sovereign of Man, ceded in 1266 to Alexander III. all his claims and interest in the sovereignty and episcopacy of Man for the sum of 4000 marks, and an annual pension of 100 marks. The widow of Magnus, however (the late King of Man), a woman of haughty and intriguing spirit, succeeded in getting Ivar, the assassinator of her brother-in-law Reginald, placed on the vacant throne; and Alexander in 1270 sent an army, under the command of Alexander Stuart of Paisley and John Comyn, to reduce the island to a state of obedience. After a decisive battle at Ronaldsway, near Derbyhaven, in which 500 of the Manx, with their leader Ivar, were slain, the kingdom was entirely subjugated and annexed to the dominions of Alexander. This monarch, in token of his conquest, substituted the quaint device of "the three legs," which still constitutes the national emblem, for the ancient armorial ensign of the island—a ship in full sail, with the motto, "*Rex Manniæ et Insularum.*" He placed the island under the government of his nobles or thanes, whose repeated acts of tyrannical oppression at length inspired the inhabitants to throw off the Scottish yoke. Bishop Mark (Marcus Galvadiensis), a Scotchman, however, being informed of their determination, obtained their mutual consent to decide the contest by thirty champions selected from each party. The Manx champions were all killed in the contest that took place, and twenty-five of the Scottish warriors shared the same fate. This victory confirmed the conquest of the Scots; the ancient regal government was abolished, and a military despotism established.

During the contentions of Bruce and Baliol, Edward I. of England took possession of the island for a period, while two rival claimants for the throne appeared. One of these was Mary, the daughter of Reginald III.; the other Affrica or Alfrida, a daughter of Olave III., the "Black King of Man," and sister of Magnus (and aunt to Mary, the other claimant). The latter was successful; and she in 1305 conveyed by a deed of gift her right and interest in the island to her husband, Sir Simon de Montacute, whose son Sir William afterwards mortgaged its revenues to Anthony Beck, Bishop of Durham and Patriarch of Jerusalem, to whom the king made a grant of it for life. In 1313 Bruce made a descent on the island, and succeeded in driving out the English. He granted it to his nephew Randolph, Earl of Murray, during whose sway it was overrun and plundered by a numerous body of Irish under Richard de Mandeville.

In the reign of Edward III. Mary Waldebeof, daughter of the previous claimant, and grand-daughter of Reginald III., presented her claims to the sovereignty of the island, and solicited the protection and assistance of that monarch. The king allowed her title, and by giving her in marriage to William Montacute, Earl of Salisbury (the grandson of Sir Simon Montacute and Alfrida), thus united in their persons the rights of the two lines of descendants of Olave the Black to the kingdom of Man. With the aid of the English king, the earl was enabled to expel the Randolphs from the island; and in the year 1344 he was with much pomp crowned King of Man. Thus, to the great joy of the people, was the government restored to its rightful possessors. In the year 1393 the Earl of Salisbury sold to Sir William le Scroop "the Isle of Man, with the title of king, and the right of being crowned with a golden crown."

Sir William le Scroop, afterwards Earl of Wiltshire, being attainted and beheaded for high treason, the island in 1399 was bestowed on Henry Percy, Earl of Northumberland, but he having been attainted and banished, Henry IV. made a grant of it to Sir John Stanley for life. This deed was cancelled, and a new patent passed the Great Seal in 1406, bestowing the island, Peel Castle, and lordship of Man, and the isles appertaining thereto, with all the royalties, regalities, and franchises, with the patronage of the see, on him and his heirs, to be held of the crown of Great Britain, *per homagium legum*, paying to the king a cast of falcons at his coronation.

The lords of the House of Stanley made frequent visits to the island, but governed it chiefly by lieutenants, who occupied the castles of Peel and Rushen, having them fortified with strong garrisons. Various tumults arose, occasioned by the infraction of ancient customs and popular liberty; and in 1422 fourteen persons were drawn by wild horses, quartered and beheaded. Eventually authority was delegated to Henry Byron, whose penetration and policy soon restored order. He remodelled the House of Keys, relieved the people of many oppressive enactments, and by his wisdom and circumspection rendered his regency one of the most popular in the insular history. John Stanley died in 1432, and was succeeded by his son Thomas, who was created Baron Stanley by Henry VI., and died in 1459. Thomas his son succeeded him, and was created Earl of Derby by Henry VII. for the aid he rendered to him with his forces at Bosworth; and he is remarkable in English history as having crowned Henry on that memorable battle-field. This nobleman's son Thomas, the second Earl of Derby, relinquished the title of King of Man, as he preferred "being a great lord, to a petty king." He died in 1522. Edward, the third earl, son of the last-named Thomas, was a great favourite with Henry VIII., and was reputed to have been very rich and munificent; during his time the revenues were confiscated, and the edifice dismantled, of the venerable abbey of Rushen, which was the last of all the monasteries dissolved by the rapacious and sanguinary Henry VIII. He died in 1572, and was succeeded by his son Henry, the fourth Earl of Derby. He died in 1594, leaving two sons, Ferdinand and William, who in time became lords of Man. The title of William was disputed by the three daughters of Ferdinand: with these, however, he effected a compromise; and in 1610 obtained an "act for assuring and establishing the Isle of Man in the name and blood of William, Earl of Derby." He, in 1637, being tired of public life, resigned his dignities to his son James, so celebrated in history as "the great Earl of Derby."

During the civil war the island remained steadily attached to the interests of the king, and was one of the last places that yielded to the authority of Cromwell. After the relief of Lathom House and the battle of Bolton, the noble earl retired to the Isle of Man, where he continued to reside, actively engaged in protecting his interests, until 1651. In that year he again proceeded to England, where he raised a force, joined the royal army, was defeated and taken prisoner at Worcester, and beheaded at Bolton, October 16, 1651. The defence of the island was undertaken by the heroic Lady Derby, who was then in Castle Rushen; but William Christian, the receiver-general, on the appearance of a hostile fleet, surrendered the castle without resistance, to which act of treachery there is little doubt that he had been bribed.

On the decapitation of Earl James, the Parliament granted the island to General Fairfax in consideration of his services, who held it until the Restoration, when it was restored to Charles, the eighth earl (the son of Earl James), in 1660. On the death of Earl Charles in 1672, he was succeeded by his son William, the ninth earl, who took but little interest in his Manx property, and dying without issue in 1702, was succeeded by his nephew James (a younger son of Charles, the eighth earl). At this time the lordship of Man was approaching to dissolution. The leases, which had been granted for three lives, having nearly expired, and no provision having been made relative to their renewal, the neglect of agriculture became so general that repeated seasons of scarcity and famine occurred, and the people were wholly given up to the fishery and the pursuit of the contraband trade. Bishop Wilson energetically drew attention to this injurious system, and his powerful efforts being seconded by a firm but respectful remonstrance from the insular legislature, prevailed upon his lordship to confer in 1703 upon his Manx subjects the Act of Settlement (very justly called the Manx Magna Charta), and which may be considered one of the most important occurrences in the civil history of the island, as by it the lessees of estates were finally established in their possession, and their descent assigned in perpetuity, on the payment of certain fines, rents, and dues to the lords. James died in 1736 without issue, and was the tenth and last earl of the noble and illustrious House of Stanley, who had been sovereigns of the isle for more than 300 years.

The lordship of Man then devolved on James, second Duke of Athol, a descendant of the Lady Amelia Sophia Stanley (the youngest daughter of the noble James, the seventh Earl of Derby). In 1726, in order to put an end to the contraband trade of the island, which had become so extensive as materially to affect the revenue of Great Britain, an act of Parliament was passed authorizing the purchase of all the royalties and revenues of the island; but though many overtures were made by the government, no result followed till after the death of the duke, whose only daughter Charlotte, the Baroness Strange, being married to her cousin John, the next male heir to the dukedom, conveyed to him the lordship of Man in her own right. Proposals for the purchase were revived in 1765, and measures having been introduced into Parliament for the more effectual prevention of the illicit trade of the island, the duke and duchess agreed to surrender the sovereignty and its revenues for L.70,000. They reserved the manorial rights, the patronage of the see, and some emoluments and perquisites, respecting which a misunderstanding arose in consequence of the British government claiming more than the duke and duchess intended by the treaty to relinquish, and therefore a further sum of L.2000 per annum was granted as an annuity to the duchess out of the Irish revenue: the sovereignty of the island thus became vested in the crown of England. By the Act of Revestment the island was more closely united to the parent country, and its prosperity has ever since been progressively advancing, though its original and independent form of government has not experienced any material change. On the ground of inadequate compensation, their son John (the fourth duke) presented petitions to Parliament and the Privy Council in 1781 and 1790, but unsuccessfully, until the year 1805, when an act was passed assigning to him and his heirs, as an additional grant, one-fourth of the revenues of the island, which was afterwards commuted for L.3000 per annum for ever.

In 1825 an act passed both houses of Parliament, at the instance of the lords of the Treasury, authorizing the lords of the Treasury to treat with the duke for the purchase of his remaining interest in the island. The duke being very unpopular at the time, and much dissatisfied with his position in the island, willingly embraced the proposal, and the valuation was left to arbitrators appointed on both sides. These in the year 1829 awarded him the further sum if L.416,114 for his rights in and over the soil, as lord of the manor, as follows :—

For the customs revenue	L.150,000
Rents and alienation fines	34,000
Tithes, mines, and quarries	132,114
Patronage of the bishopric, with fourteen advowsons, the aggregate value of which was L.6000	100,000
Total	L.416,114

Thus was the island, with all its privileges and immunities, ceded to the British government.

MANAAR, an island situate on the N.W. coast of Ceylon, giving name to the gulf which separates Hindustan from Ceylon. The island, which is about 15 miles in length by 3 in average breadth, is separated from Ceylon by an arm of the sea about 2 miles broad, and at low water almost dry, excepting a small channel in the middle, of no greater breadth than about 30 or 40 yards. The distance from the western point of this island to that of Ramiseram is 12 leagues, and the intervening space is occupied by a line of sandbanks called Adam's Bridge, but which, according to a tradition of the Hindus, was constructed by their demigod Ram when he invaded Ceylon. Between these two islands small boats constantly ply, and thus keep open the communication between the two coasts. This island, which was first occupied by the Portuguese in 1560, was taken from them in 1658 by the Dutch, who banished thither their refractory subjects. It was subsequently transferred to the British. A survey of the gulf was completed a few years since, and resulted in the formation of the Paumbaum Passage, the particulars of which will be found under that head. E. Long. 80., N. Lat. 9. 3.

MANACOR, a town in Majorca, is situate in a fertile valley, 30 miles E. of Palma. It is substantially built, with spacious streets and squares; and the chief buildings are,—the palace of the ancient kings of the island, a church, a chapel of ease, two schools, an hospital, &c. Brandy, wine, &c., are produced here, and there is a considerable trade in corn, fruits, cattle, &c. Pop. (1845) 9642.

MANAGUA, or LEON, *Lake of*, a lake in Nicaragua, Central America, between Lat. 12. 16. and 12. 40. N., Long. 85. 40. and 86. 30. W.; 156 feet above the Pacific, and 176 feet above the Atlantic. Length, between 50 and 60 miles; greatest breadth, 35 miles. It is situated on the northern slope of the ridge of hills which traverses Central America, connecting the Rocky Mountains in the N. with the Andes in the S. It is of an irregular shape, and the depth varies from 2 to 40 fathoms. The town of Managua is situate on the S.W. shore, 32 miles S.S.W. of Leon, and consists for the most part of low huts and houses arranged in long streets. It has two churches, one of which stands in the middle of a large square, while the other is distinguished by a white gateway in front. The inhabitants are chiefly the aboriginal natives. They are very industrious, and have great skill in imitating foreign articles. Pop. 12,000.

MANAH, a town of Northern Hindustan, in the district of Kumaon, on the north-eastern frontier. It contains 150 or 200 houses, with from 1400 to 1500 inhabitants, who are above the middle size, stout, and well formed, and seem to be of a race between those of Tartary and Hindustan. The houses are two storeys in height, and constructed of stone covered with small deal planks. During the winters, which are very severe, the inhabitants emigrate to the south. A considerable trade is carried on between this place and Lahdak by means of sheep and goats, which are accustomed to the bad roads on the mountains. They import saffron, borax, gold-dust, musk, &c., and export Benares manufactures, and a few light European articles. E. Long. 79. 32., N. Lat. 30. 46.

MANAYUNK, a town in the county of Philadelphia, state of Pennsylvania, North America, is situate on the left bank of the Schuylkill River, 7 miles N.N.W. of Philadelphia, and 89 miles W. by S. of Harrisburg. The town is irregularly built on the slope of a hill near the river, and the upper part contains several fine houses and churches. It has six Protestant and two Roman Catholic places of worship. There is abundance of water-power at Manayunk, and the town contains about sixteen cotton factories, besides three paper-mills, and other manufactories. The river is crossed by two bridges. Pop. (1853) about 7000.

MANCHA, LA, a territory and province of Spain, in New Castile. The territory of La Mancha comprised part of each of the four provinces of Toledo, Albacete, Cuenca, and Ciudad-Real—the latter almost wholly, whence it is still called the province of La Mancha. It is the second province of Spain in point of extent, containing 663 square leagues of level country. From this circumstance, and the apparent scarcity of water and the want of trees, and from the population being concentrated at various points, instead of covering the country,—the whole province presents to the traveller the arid and cheerless aspect of a desert. The principal river is the Guadiana, which rises about 2 leagues from Villarubia, and enters the province of Badajoz near Castilblanco. Most of the other rivers of the province—the Azuer, Jabalon, Gigüela, &c.—flow into the Guadiana. The Guadalmena has also a course of about 6 leagues through part of La Mancha. No advantage, however, is taken of these and the other streams in the province for irrigation, the inhabitants depending entirely on the rain; a neglect for which they have been frequently visited by famine. Besides the numerous streams, there are few spots where water may not be found a few yards beneath the surface; but neither of these supplies has been turned to good account. This province abounds in valuable mines; those of cinnabar in Almaden were well known to the ancients. In 1844 there were thirty-seven of lead and twelve of copper, and a few of silver. There are, besides, manufactures of saltpetre in several parts; quarries of fine stone at Santa Cruz and elsewhere: the white-chalk or *tierra del viso*, is famous. The agricultural products are,—wheat, barley, rye, various legumes, saffron, &c. A good deal of wine and brandy, but not much oil, is made. Hemp is grown in some districts. The mules reared in La Mancha are considered the best in or out of Spain. There are manufactures of woollen cloths, earthenware, saltpetre, gunpowder, and some other articles. The lace of Almagro is exported to all quarters of the kingdom. Grain is exported chiefly to Murcia, Valencia, and Madrid, in which city also the wine and oil of the province find a market. A so-called university existed in Almagro till 1824, since which time there are only primary institutions in La Mancha; nor are these numerous or well distributed. The province contains ten partidos, with a population in 1847 of 277,788.

MANCHE, LA, a department in the N. of France, forming part of the old province of Normandy, and lying between N. Lat. 48. 35. and 49. 40., W. Long. 0. 43. and 1. 50. It is bounded on the W., N., and N.E. by the Manche or English Channel, from which it derives its name; on the E. by the departments of Calvados and Orne; and on the S. by those of Ille-et-Vilaine and Mayenne. Length, 90 miles; average breadth, 27 miles; area, 2291 square miles. The department is traversed from S. to N. by a range of hills of small height called Cotentin, which branch off from the Armoric ridge, and slope gradually towards the sea on either side. The coast is in some parts rugged and precipitous; but in others there are large tracts of sandy beach. There are several pretty good harbours, of which Cherbourg, La Hougue, Granville, Regneville, Carteret, &c., are the chief. The coast is skirted with many islands, single and in groups, such as Mont St Michel, the Chaussey group, Pelée, Tatihou, and St Marcouf, most of which are fortified and garrisoned. The main island of the Chaussey group is remarkable for its granite quarries, and, except by the workmen in these, it is uninhabited. There are no large rivers in this district, the most considerable being the Vire, which enters La Manche in the S.E., and, after flowing in a northerly direction for about 50 miles, falls into the channel at the boundary between this department and that of Calvados. The greater part of the rocks here are of primary formation; but towards the E., near the banks of the Vire, there are to be found deposits of a more recent origin, such as lias, sandstone, limestone, and slate. The country is in general undulating, the soil rich, and the climate moist and mild. La Manche is very extensively cultivated, and the produce of grain is more than sufficient to supply the wants of the inhabitants. Potatoes, hemp, flax, and fruits, are also among its productions, and more than 22,000,000 gallons of cider are made every year. A considerable portion of the land is laid out in pasturage, which is excellent; and fine breeds of horses and cattle are reared, the former being much prized for military purposes. The quantity of live stock is estimated at 92,000 horses, 210,000 head of horned cattle, 320,000 sheep, and 85,000 pigs. Game and fish also abound. Mining operations are carried on to a large extent in iron, lead, and coal; and there are, besides, quarries of granite, marble, slate, limestone, &c., as well as extensive salt marshes along the coast, which are a source of much wealth. The principal manufacturing employments of this department are the working of iron, zinc, and copper, and the making of woollen and cotton stuffs, of cloth, lace, paper, glass, leather, &c. In many of the coast towns there is a good deal of ship-building; and the commerce with the channel is considerable in the agricultural produce of the country, as well as in the articles of manufacture. The department is divided into six arrondissements, and contains six tribunals of primary instance, and four of commerce; six colleges, one normal school, five superior, and 1225 elementary schools. It belongs to the sixteenth military division, and sends four members to the legislative body. The capital is St Lô. The population in 1851 of the various arrondissements was as follows:—

	Cantons.	Communes.	Inhabitants.
St Lô	9	117	99,099
Coutances	10	138	130,475
Valognes	7	118	92,238
Cherbourg	5	73	85,397
Avranches	9	124	117,032
Mortain	8	73	76,641
Total	48	643	600,882

MANCHESTER,

THE second town of the empire in point of population, and the most important on account of its manufactures, is situate almost at the south-eastern extremity of the county of Lancaster, and is distant 186 miles N.W. by N. from London. The site of the original town was early occupied by a fort, which the Celts, migrating from the Continent, and gradually spreading from the north, planted at Castle Field, upon the bank of the River Irwell. Whitaker, the learned historian of the ancient town, gives this station the name of "*Mancenion*, or the Place of Tents." Possession was taken of it by the Romans about a century after its formation (A.D. 72), and they continued masters of it during three centuries, until their final departure from the island. Several of the great Roman roads, traces of which still remain, centred at this point. The fort subsequently fell into the hands of the Pictish invaders, but after a lengthened struggle, was wrested from them by the Saxons, who repaired the damage to the "Aldport Town," brought the people into due subjection to the lord or *thegn*, whose baronial hall covered the space of the existing Chetham's College, and built the churches of St Mary and St Michael. "Manigceastre," as Hollingworth styles the town, was occupied by the Danes about the year 870; and little is known of its succeeding history until, in the apportionment of territory made by the Norman conqueror, Manchester was assigned to William of Poictou, from whom the lordship of the manor has descended by marriage, hereditary succession, or purchase, through the families of Grelley, De la Warre, West, and De Lacey, to "Mossley of the Hough," whose successor, Sir Oswald Mosley, Bart., was the possessor of the manorial rights and property; but on corporate powers and privileges being obtained by Manchester in 1840, these rights, and much valuable property, were sold by him to the new corporation. The Grelleys, De la Warres, and Wests, sat as barons in Parliament; and Thomas de Grelley granted in 1301 a "great charter of Manchester," which, however, has no existing validity.

The Reformation was violently opposed in Manchester; Collyer, the warden of the "College of the Blessed Virgin," Bradford, and Pendlebury, were zealots in the religious controversies it excited; and Bradford died a martyr. In Elizabeth's reign, Persons and Campion, the noted Jesuits, plotted in these districts; and from Ancoat's Lane, now a densely peopled quarter of the town, one of the Martin Marprelate presses sent forth its stirring missives. The clergy were said to be so hostile to the progress of the Reformation, that the "college" was dissolved in the reign of Edward VI.; in Elizabeth's reign a commissioner's court to promote the Reformation was established; and the most severe measures were taken against recusants, who swarmed in the dungeons of Manchester. In 1584 some were executed, one at Manchester, and their heads exposed on the "college." In the "great rebellion," Manchester took a very prominent part, the anti-monarchical party having the ascendancy. A brawl, which arose between the followers of Lord Strange (afterwards the ill-fated Earl of Derby) and the inhabitants, was magnified into a great battle, and proclaimed in the metropolis as "the beginning of civil warres in England, or terrible news from the north;" Lord Strange being impeached by the Lower House for his conduct in the affair. Subsequently the town was formally besieged by his lordship's forces, but they were driven off; and the troops which had been levied for the defence of the place were engaged in various expeditions, one of which was the noted attack on Lathom House. When the warfare had ceased in England, sequestrators were sent down, who alienated the revenues of the college; presbyteries were established throughout the whole of Lancashire; Manchester was the central point of one "classical division," and the provincial synod met there. In these troubled times the warden Heyrick, a man of eminent endowments, acted a distinguished part.

Passing over another long interval, the people of Manchester are found espousing the cause of the Chevalier St George, for their devotion to whom five of the inhabitants were executed in the town. In 1745 they again stood forth in favour of the young Prince Charles; one of the localities in which the plans for his invasion of the monarchy were concocted being in the immediate vicinity, at Jackson's Ferry, near Didsbury. In the summer previous to his public appearance in Scotland, the prince secretly visited Manchester, and was entertained for a considerable time at Ancoat's Hall, the seat of Sir Oswald Mosley, the lord of the manor. The Pretender's forces entered the town on the 28th and 29th of November. They did not receive a very cordial welcome; and when they marched forward by Macclesfield towards Derby, the prince had enlisted from the inhabitants only about 300 followers, and these chiefly of the lower order. In his subsequent precipitate retreat through Manchester, his reception was less agreeable than before. The "Manchester regiment" were left to garrison Carlisle, which place speedily surrendered to the Duke of Cumberland, and they were made prisoners. Many were sent abroad; some of the leaders suffered decapitation, and their heads were exhibited on the top of the Manchester Exchange.

The later history of the inhabitants is of a more loyal character. They were very active in the American contest, the war of the French revolution, and the more recent struggle with Napoleon, raising many regiments of volunteers, and otherwise affording their aid very freely. The first Sir Robert Peel, then residing near Bury, but who was virtually a Manchester manufacturer, his establishment being in that town, contributed money, and raised a troop of volunteers; and in the year 1798, Peel and Yates subscribed L.10,000 to the "voluntary contribution for the defence of the country." From this period to the close of the war in 1815, the people of Lancashire suffered from dear food, high taxes, and by the abstraction of able-bodied men who enlisted for soldiers; and when peace was restored, the corn laws, and the redundancy of labour consequent upon the disbanding of the army, led to a continuance of distress, as also of dissatisfaction. The distress thus engendered, and the political ferment of the times, gave rise, in August 1819, to the noted "Peterloo" affair, in which a countless mass of people, having assembled for the alleged object of petitioning the House of Commons for a reform of Parliament, and the repeal of the corn laws, was dispersed by the yeomanry and the troops of the line. The Radicalism of these times has since cooled down into a more mitigated species of Liberalism. In 1830–31 many very numerous meetings were held in favour of the Reform Bill; and when it became a law, the electors returned as their representatives to Parliament the Right Honourable C. Poulett Thomson, then vice-president of the Board of Trade, and Mark Philips, Esq., both gentlemen of liberal politics. Manchester had previously sent representatives in early times. In the year 1366 the Sheriff of Lancashire, being required to cause the return of burgesses to Parliament from boroughs of sufficient importance to require representation, reported there was no city or borough in the county willing to accept the burdensome honour, "by reason of their inability, low condition, or poverty." But in Cromwell's time, July 1654, Manchester sent Mr Charles Worsley, and in the next year Mr R. Ratcliffe, to represent her interests.

Manchester has been a place of trade from a very early period. In the most remote antiquity the people traded with the Greeks of Marseilles, and with other foreigners, through Ribchester, then a considerable port on the Ribble, which river is now no longer navigable so far inland. In the reign of Henry VIII. a law was enacted to remove the right of sanctuary from Manchester to Chester, on the ground that it caused the resort hither of idle and dissolute persons, to the injury of the "trade, both in linens and woollens," for which the place was "distinguished," and which gave employment to "many artificers and poor folks," whose masters, "by their strict and true dealing," caused "the resort of many strangers from Ireland and elsewhere, with linen, yarn, wool, and other necessary wares for making of cloth, to be sold there." Camden speaks of the town as "of great account for certain woollen clothes there wrought;" and in the year 1650 the people are described as "the most industrious in the northern parts of the kingdom." The disturbances in France and the Netherlands had tended not a little to the growth of manufactures in the town, by causing the settlement of French and Flemish artisans in Lancashire. Early in the last century it was mentioned as a remarkable fact, that in Manchester and Bolton alone goods to the amount of L.600,000 were annually manufactured. The trade appears, in fact, to have attained to as large a growth as was possible in the then confined state of mechanical knowledge. It was not until an impulse was given to invention, and that splendid series of machines was produced, of which the effects have been so amazing, that Manchester became really a place of commercial eminence and great resort.

The first of these inventions, in point of date, was the water-frame, of which Arkwright, in 1769, claimed to be the originator. In 1770 the spinning-jenny of James Hargreaves was first heard of; and in 1779 Crompton's mule-jenny was invented; while the "throstle" became an important modification and improvement of the water-frame. In 1785 Arkwright took out a patent for improved carding, drawing, and roving machines. The steam-engine of Watt dates about the same time, although there were sundry modifications of it both before and afterwards. The power-loom, for which Cartwright took out his last patent in 1787, but which underwent many changes before it could be considered as a practical machine, completes the list of early discoveries. There were, of course, various inventions subordinate to these. In the beginning of the present century, a machine was constructed which outvied all others in importance; it was the self-acting mule, the invention of Messrs Sharp, Roberts, and Company, of Manchester. Their last patent was taken out in 1830, and there are several millions of spindles at work on the principle of spinning yarn almost independently of human labour. Smith of Deanston, and other inventors, have subsequently contrived self-acting mules, and now the self-acting principle of spinning is fully established, and is applied universally to coarse yarns.

The history of this invention is fraught with instruction to the working-classes. Attention was first directed to the possibility of contriving a self-acting mule, in consequence of the frequency of "turns-out" amongst the spinners, and the intolerable domination which they were enabled to exercise, from the circumstance of a comparatively small class of workmen having it in their power at any moment to suspend the whole trade of cotton-spinning. One "spinner" had three or four young hands immediately dependent upon himself; he had also four or five virtually dependent on him, inasmuch as they being occupied in preparing the raw cotton for him to spin, if he took a fit of idleness or insubordination, the preliminary processes were of course suspended. In the same way, if the spinners as a body became idle, the weavers, and eventually the bleachers, spinners, and printers, were brought to a stand; in fact, the whole cotton trade was locked up, and misery and privation were the immediate and wide-spread results. These considerations induced master spinners to call into play the talent of ingenious men, for the purpose of constructing such machines as would give more stability and regularity to the processes of spinning. The self-acting principle has the virtue of being easily grafted on the older fashioned mules, a third of the value of which is sacrificed in so transforming them.

But the mere discovery of the early machines was of little benefit to the country, so long as they could be restricted in their use at the caprice of the patentee. Accordingly, through the instrumentality of Mr Peel, an association of master manufacturers was formed, and a subscription to take proceedings for setting aside Arkwright's patents was entered into, upon the principle of each spinner paying a shilling per spindle for as many as he used. The original subscription list is still in existence; the number of spindles subscribed for was about 20,000, being not more than a fourth of the number now employed by many large manufacturers. In 1781 and 1785 Arkwright's patents were annulled, and the cotton trade took a gigantic stride. The exports, which in 1701 were only to the value of L.23,253, and in 1780 only L.355,060, had risen in 1781 to L.1,101,457, and in 1800 to L.5,406,501; but gradually expanding, the whole exports of the cotton industry amounted in 1856 to upwards of L.38,000,000. The import of raw cotton, which in 1751 was only 2,976,610 lb. weight, was in 1780 upwards of 6,700,000; in 1790, 31,500,000; in 1800, 56,000,000 lb.; and in 1856, 1,000,021,021,000 lb. weight. In 1787 it was estimated that there were in Lancashire 41 cotton factories, in Derbyshire 22, and in Nottinghamshire 17. In 1790 the number had increased; and in 1817 Mr Kennedy of Manchester calculated that there were 110,763 persons employed in cotton-spinning, and 20,768 horses' power. In 1832 Messrs Greg of Manchester made a fresh estimate, giving the number of operatives employed in the cotton-spinning and weaving mills only of Great Britain, 160,000. In the year 1782 a great panic was excited in Manchester by the announcement that 7012 bags of cotton had been imported between December and April.

In 1788 a meeting was held in Manchester to consider the great depression under which the cotton manufacture was labouring from the "immense importation" of Indian goods; and shortly afterwards the cotton manufacturers of Lancashire, in conjunction with those of Scotland, appointed deputies to obtain an interview with the king's ministers, and solicit permission to erect themselves into a company of traders, with privileges similar to those enjoyed by the East India Company. At this time it was estimated that the cotton manufacture employed 159,000 men, 90,000 women, and 101,000 children,—an exaggerated number. In truth, until the passing of the Factory Act, and the appointment of inspectors and superintendents under its authority, there were no means of ascertaining the number of hands employed either in the whole country or in districts. The number of hands employed in Manchester in 1836 was as follows:—

Parish of Manchester.	Under 13.		13 and under 15.		15 and under 18.		Above 18.		Total.	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
IN COTTON MILLS.										
Ardwick	34	25	36	88	30	82	194	180	294	375
Beswick	9	12	21	34	16	28	127	94	173	168
Droylsden	5	5	11	21	14	31	39	70	69	127
Gorton	39	15	40	98	73	94	176	260	328	467
Crumpsall	11	12	42	37	18	40	66	102	137	191
Levenshulme	4	6	23	23	11	9	33	42	71	80
Collyhurst	...	...	19	26	4	22	30	76	53	124
Manchester	808	561	1999	1821	1126	1535	5592	7178	9525	11,095
Chorlton-on-Medlock...	217	132	480	463	258	361	1102	1323	2057	2270
Failsworth	...	...	14	9	8	22	35	20	57	51
Newton	...	...	40	16	9	6	35	36	84	58
Salford	51	40	242	218	114	242	539	997	946	1497
Hulme	49	32	66	67	44	74	219	303	378	476
Total cotton...	1832	1275	5284	5040	3043	4349	14,288	18,546	24,447	29,210
Total silk	404	880	214	584	114	520	426	829	1158	2813
WOOLLEN.										
Salford	...	...	12	...	4	...	44	...	60	...
WORSTED.										
Manchester	6	7	8	18	4	15	15	52	33	92
FLAX.										
Broughton	8	11	28	35	25	51	43	63	104	160
Droylsden	...	1	3	3	...	2	5	6	8	12
Total Flax	8	12	31	38	25	53	48	69	112	172
Grand total	2350	2174	5594	5610	3190	4937	14,821	19,512	25,810	32,303

The following is a Return of the Hands not included in the above Townships, which, added to the above, will give the Complete Numbers for the Parish of Manchester:—

	Under 13.		13 and under 15.		Under 18.		Above 18.		Total.	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
Cotton	117	127	517	542	280	301	1553	1963	2467	2933
Silk	4	...	13	2	5	5	41	40	63	47
Total	121	127	530	544	285	306	1594	2003	2530	2980

Numberless manufacturers had works on the borders of Cheshire, Derbyshire, Yorkshire, and Staffordshire, whilst their warehouses were situate, and all their transactions centred, in Manchester.

The following is a summary of mills in the county of Lancaster, and the number of steam-engines and water-wheels, with the horse-power and the number of hands employed in the year 1835:—

Mills.	Number of Mills.	Steam.		Water.		Total hands employed.
		Number of Engines.	Horse Power.	Number of Wheels.	Horse Power.	
Cotton	576	717	20,303½	231	2,851	122,991
Woollen	99	50	747	95	761½	4,575
Worsted	8	7	123	5	102	1,076
Flax	19	19	550	4	70	3,566
Silk	22	24	387½	3	24	5,382
Total	724	817	22,111	338	3,808½	137,590
Of which in the parish of Manchester	143	191	6,631	8	86	41,958

The number of power-looms employed was as follows:—

Number of Mills.	Parishes.	Power-Looms.				
		Cotton.			Woollen.	Silk.
		Calico.	Fustians.	Small Wares.		
66	Manchester, pt. of	12,708	2,381	545	20	306
1	Middleton, part of	408	...	...	...	...
2	Eccles	...	416	...	...	60
45	Bury	2,067	6,954	...	280	...
35	Whalley	4,737	287	...	457	...
1	Rochdale, part of	30	...	...	...	...
1	Chorley	340	...	...	...	...
1	Leyland	190	...	...	...	...
16	Blackburn	4,007	249	...	...	...
8	Preston	2,356	...	...	...	...
4	Wigan	4,532	...	...	...	...
5	Lancaster	1,144	...	...	...	...
2	Prestwich, part of	...	111	...	...	...
1	Radcliffe	...	72	...	...	...
7	Bolton	1,085	546	68	...	...
6	Dean	186	602	...	...	...
	Totals	33,790	11,618	613	757	366
201	Grand total...	46,021			757	366

In addition to these, Mr Trimmer and M. Bates returned the following from their respective superintendencies:—

Districts.	Cotton.		Woollen.	
	Mills.	Number of Power-Looms.	Mills.	Number of Power-Looms.
In Mr Trimmer's district of Lancashire	78	14,137	5	385
In Mr Bates's ditto (Ashton-under-Lyne)	11	4,018	...	...
Total	89	18,155	5	385

Of which about 485 were in the parish of Manchester.

Weekly Earnings of Workers in Cotton Factories, Manchester and Neighbourhood, 1857, *for sixty hours' labour.*

Occupations.	In coarse Mills.					In fine Mills.				
	s.	d.		s.	d.	s.	d.		s.	d.
Scutching or cotton cleaning overlookers, men......	15	0	to	20	0	15	0	to	21	0
... ... tenters, women	7	0	„	9	0	7	6	„	10	0
Carding overlookers, men......	20	0	„	32	0	20	0	„	40	0
... grinders, ...	12	0	„	18	0	14	0	„	18	0
... strippers, ...	13	0	„	15	0	13	0	„	15	0
Bobbin-frame or roving overlookers, men..........	...					25	0	„	33	0
Bobbin-frame first tenters, women	8	0	„	9	6	8	0	„	9	6
... ... second ...	8	0	„	9	6	8	0	„	9	6
... ... third ...	8	0	„	9	6	8	6	„	10	0
Comber tenters.................	...					8	6	„	9	0
Drawing-frame tenters.........	8	0	„	9	0	8	6	„	9	6
Mule-spinning overlookers, men.........................	22	0	„	30	0	22	0	„	30	0
Mule-spinners, men.............	16	0	„	22	0	25	0	„	50	0
... piecers, boys, girls, men, and women...	5	0	„	10	0	5	0	„	12	0
Throstle - spinning overlookers, men................	15	0	„	30	0	...				
Throstle-spinners, girls and women	5	0	„	10	6	...				
Power-loom weaving overlookers, men................	18	0	„	36	0	...				
Power-loom warpers, men......	20	0	„	30	0	...				
... dressers, men.....	21	0	„	30	0	...				
... weavers, boys, girls, men, and women...	8	0	„	18	0	...				
Reelers..............................	7	0	„	11	0	7	0	„	12	0
Roller coverers....................	15	0	„	30	0	15	0	„	30	0
Steam-engine tenters...........	25	0	„	40	0	25	0	„	40	0
... stokers..........	15	0	„	18	0	15	0	„	18	0
Watchmen	16	0	„	21	0	16	0	„	21	0
Mill mechanics....................	24	0	„	32	0	24	0	„	32	0
Mill joiners.........................	24	0	„	28	0	24	0	„	28	0

Various local circumstances have combined to scatter the cotton trade over Lancashire, Cheshire, and Derbyshire. Thus, for example, Preston has become a large depôt of the cotton manufacture, the price of labour and local considerations uniting in its favour; Lancaster, for the same reason, is also rising into manufacturing importance.

The subjoined table shows the difference in the price ot labour at Manchester and Glasgow, the great centres of the cotton trade in England and Scotland, in 1833:—

Age.	MALES.						FEMALES.					
	Number Employed.		Aver. Weekly Wages.				Number Employed.		Aver. Weekly Wages.			
	Manchstr.	Glasgow.	Manchstr.		Glasgow.		Manchstr.	Glasgow.	Manchester		Glasgow.	
			s.	d.	s.	d.			s.	d.	s.	d.
Below 11	246	283	2	3½	1	11¾	155	256	2	4¾	1	10½
11 to 16	1169	1519	4	1¾	4	7	1123	2162	4	3	3	8¾
16 to 21	736	881	10	2½	9	7	1240	2452	7	3½	6	2
21 to 26	612	541	17	2½	18	6	780	1252	8	5	7	2¼
26 to 31	355	358	20	4½	19	11¼	295	674	8	7¾	7	1
31 to 36	215	331	22	8½	20	9	100	255	8	9½	7	4½
36 to 41	168	279	21	7¼	19	8½	81	218	9	8¼	6	7¾
41 to 46	98	159	20	3½	19	6	38	92	9	3½	6	6½
46 to 51	88	117	16	7¼	19	2	23	41	8	10	6	10
51 to 56	41	69	16	4	17	9¾	4	18	8	4½	6	1½
56 to 61	28	45	13	6½	16	1¼	3	16	6	4	6	0
61 to 66	8	17	13	7	17	7	1	7	6	0	5	5
66 to 71	4	15	10	10	15	9½	1	2	6	0	4	0
71 to 76	1	11	18	0	10	11	...	...	......		......	
76 to 81	1	5	8	8	9	6	...	...	......		......	
	3770	4630					3844	7445				

Amongst other subjects to which the factory commissioners directed their attention, the health of factory operatives occupied, of course, much of their time, and various modes of test and comparison were adopted. Dr Mitchell, one of the medical witnesses examined, made the subjoined estimate of the amount of sickness yearly amongst various classes of operatives:—

	Days of Sickness.
In the Staffordshire potteries, to the age of 61	9·3 per man.
In silk mills, to the age of 61	7·8
In woollen do..	7·8
In flax do...	5·9
In cotton mills in Glasgow	5·6
East India Company's servants..........................	5·4
Labourers in Chatham dockyard	5·38
In Lancashire cotton mills[1]............................	5·35
Ditto ditto under 16 years of age	3·14

A number of children were also measured, and the result was as under:—

	Inches.
Boys in factories measured	55·28
Ditto not in factories ditto	55·56
Girls in factories measured	54·951
Ditto not in factories ditto	54·976

The commissioners also inquired into the state of education amongst manufacturing operatives, and gave the result of an examination of 50,000 work-people as follow:—

	Proportion in the Hundred.			
	Could read.	Could not read.	Could write.	Could not write.
Lancashire	83	17	38	62
Cheshire	90	10	47	53
Yorkshire	85	15	48	52
Derbyshire	88	12	43	57
Staffordshire..............................	83	17	61	39
Leicestershire	80	20	40	60
Notts	88	12	42	57
Norfolk, Suffolk, Essex	81	19	26	74
Wiltshire	85	15	38	62
Somersetshire	89	11	26	74
Devon	96	4	51	49
Gloucestershire..........................	92	8	40	60
Worcestershire..........................100		...	77	23
Warwickshire	88	12	38	32
Average............	86	14	43	57
Average in Scotland............	96	4	53	47
... Ireland............	90	10	44	56

Upon this subject a more elaborate and careful investigation was made in 1834 and 1835 by the Manchester Statistical Society, from which it appeared that there were in the borough of Manchester 43,304 children receiving education, or 21·65 per cent. of the population; and in the borough of Salford 12,885 children, or 23·4 per cent. Of these there were in Manchester 10,108, and in Salford 3131, who attended only day or evening schools; 10,011 in Manchester, and 3410 in Salford, who attended both day and Sunday schools; and 23,185 in Manchester, and 6344 in Salford, who attended only Sunday schools. It further appears that in Manchester two-thirds, and in Salford twenty-two and a half per cent., of the children between five and fifteen years of age were receiving instruction.

The total quantity of yarn spun in England in 1835 was 248,814,531 lb. Mr Burn estimated the number of spindles employed in producing it at 11,152,990; and, calculating the capital in the usual way, namely, at 17s. 6d. per spindle, it would appear that L.9,758,864 was the amount embarked in the cotton spinning. From the same excellent source is derived an estimate of the value of the goods manufactured, and the yarn and thread spun in 1835.

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[1] Evidence was given by three surgeons at Bolton and a physician at Stayley Bridge, to the effect that the high temperature of mills is not injurious, if there be proper ventilation; that scrofula is not frequent; that asthma and bronchitis are generated in the card-rooms; that pulmonary complaints are of most frequent occurrence amongst factory operatives; but that they are not more liable to sickness than out-door labourers. It is an established fact, that operatives in factories had an exemption from cholera when it raged in Manchester, which was not experienced by other classes.

Description.	No. of Yards, &c., of each Description.	Length of each Piece.	No. of Pieces, &c., of each Description.	Weight of Yarn in each Piece.		Total Weight of Yarn exported in Goods.	Averago Price of each Piece, &c.		Value of Yarn per lb. when manufactured into Goods.		Total amount of Goods exported in 1835.
	Yards.	Yards.	No.	lb.	oz.	lb.	s.	d.	s.	d.	L.
Calicoes, printed, dyed	212,529,356	28	7,911,763	4	0	31,647,052	14	0	3	6	5,538,239
Calicoes, plain	234,164,513	24	9,756,813	5	8	53,662,471	9	0	1	7½	4,390,566
Cambrics, &c.	10,509,055	20	525,453	3	0	1,576,359	11	8	3	10¾	306,514
Velveteens, &c.	7,362,538	60	122,709	20	0	2,454,180	60	0	3	0	368,127
Quiltings, &c.	273,736	60	4,562	18	0	82,166	56	6	3	1	12,887
Cotton and linen	2,980,159	40	74,504	8	0	596,032	13	4	1	8	49,669
Ginghams, &c.	1,200,009	20	60,000	3	0	180,000	11	8	3	10¾	35,000
Ticks	207,481	50	4,150	20	0	85,000	28	2	1	3¾	5,844
Dimities	147,449	60	2,457	12	0	28,484	28	9	2	4¾	3,532
Damasks, &c.	40,700	36	1,130	10	0	11,300	27	0	2	8½	1,525
Nankeens	2,230,465	50	44,609	8	0	396,872	18	9	2	4	41,820
Lawns and lenos	19,893	20	995	2	8	2,487	11	8	4	8	580
Imitation shawls	293,858	12	24,488	2	8	61,220	7	0	2	9¾	8,571
Lace, &c.	73,522,896	40	1,338,072	0	8	669,036	11	8	23	4	780,542
Counterpanes, &c.	232,199	No.	232,199	7	0	1,625,393	7	0	1	0	81,770
Shawls and handkerchiefs	816,611	Doz.	816,611	2	8	2,041,526	6	6	2	7½	265,398
Tapes, bobbins, &c.	41,898	...	41,898	1	0	41,898	2	0	2	0	4,189
Hosiery	394,354	...	394,354	2	8	985,885	11	0	4	5	216,894
Unenumerated	L.167,440	...	...	10	0	1,674,400	...		2	0	167,440
Total weight of yarn exported in manufactured goods in 1835						97,821,761	2	6⅛	per lb.		12,279,107
Ditto „ yarn						82,457,885	1	5½	do.		6,012,554
Ditto „ thread						1,842,124	2	4	do.		214,914
Total weight of yarn						182,121,771	Total amount...				L.18,506,575

In addition to the cotton manufacture, Manchester has likewise a considerable and rapidly increasing trade in silk-throwing and weaving. The mill of Mr Vernon Royle, celebrated throughout England for its thrown silk was established in the years 1819–20, and was the first erected in the district. In 1819 there were in Manchester about 1000 weavers of mixed silk and cotton goods, and 50 of pure silk. In 1823 the number of the former had increased to 3000, and of the latter to 2500. In 1828 there were 4000 of the former class and 8000 of the latter; and in 1832 from 12,000 to 14,000 looms were employed by Manchester houses; and the throwing mills, 12 in number, but of which 2 were not then in operation, gave occupation to about 3600 hands. The state of the silk-throwing trade in 1836 was as follows:—

Summary of Silk Mills in Manchester and the County of Lancaster, 1836.

Township.	Power.		No. of Mills.	12 and under 15.		15 and under 18.		Above 18.		Total.	
	Stm.	Water.		M.	F.	M.	F.	M.	F.	M.	F.
Manchester	171	none.	8	311	623	68	276	142	444	521	1343
Salford	58	none.	3	131	370	29	108	236	136	396	594
Broughton	40	none.	1	73	303	3	62	17	76	93	441
Newton	32	none.	2	99	140	14	55	31	127	148	322
Harpurhey	3	none.	1	...	67	...	19	...	46	...	113
Heaton Norris	24	none.	1	...	...	...	...	...	...	...	...
Barton	42	none.	3	178	292	15	104	93	97	286	493
Caton	10	14	2	14	9	6	7	82	30	102	46
Ellel	20	16	2	10	10	19	9	60	62	89	81
Wray	...	unkn.	1	4	9	6	3	22	12	32	24
Ashton-under-Lyne	6	none.	1	...	...	...	...	...	...	...	...
Pennington	...	unkn.	2	...	...	...	...	...	...	...	...

It was calculated that the Manchester throwsters produced about 8000 pounds of thrown silk weekly, but that the silk looms consumed not less than 24,000 pounds, 8000 pounds of which were derived from the Macclesfield throwsters, and the remainder from Congleton, Sandbach, Newcastle, &c., very little foreign thrown being used in Manchester. The silk manufacturers having their principal establishments in Manchester, were estimated to employ not less than 18,500 looms in the weaving of pure or mixed silk goods; and, taking the usual trade average of four persons to a loom, the silk trade of the district, in all its branches, employed not less than 70,000 persons. By the returns already quoted, it will be seen that throughout Lancashire only 366 power-looms were employed in silk, of which number 306 were in Manchester, and sixty in the adjoining parish of Eccles.

The foregoing statistical information, illustrative of the great industry identified with Manchester and its tributaries of trade, extending from the earliest records chiefly to the year 1836, is retained as historical evidence of the period referred to. From that time to the present (1857) a remarkable steadiness in trade and commerce has prevailed, though distinguished by a most extraordinary increase in production, and consequently by greatly extended business ramifications. The repeal of the corn laws in 1846 gave an impulse to the cotton trade beyond all previous precedent. Employment has since been uniform and abundant. Wages have not been reduced, but on the contrary the earnings of work-people have been generally increased, and especially by the constant and unfluctuating employment afforded them. Bread has been moderately cheap; sugar, tea, coffee, and other necessaries and luxuries, have been abundant, and sold at prices so reasonable that their consumption has vastly extended; and though animal food, with butter, cheese, and milk, may be regarded as comparatively dear, yet to increased demand and consumption may be justly attributed the higher prices which are now paid for these latter articles. The general comforts of the labouring classes have, during the last ten years, been fully equal to any aggregate enjoyment ever previously experienced by them. In factories the hours of labour are by acts of Parliament essentially restricted to sixty per week, and are confined, allowing time for meals, between six in the morning and six in the evening, for five days, whilst at two o'clock P.M. on Saturdays the week's work terminates; the average labour of each day for the whole week being ten hours. This principle of limited labour is by voluntary efforts rapidly extending; bankers, merchants, and traders are closing their establishments at earlier hours than formerly; and there is a general tendency to devote Saturday afternoons to recreation. Wages are now, in the cotton trade, paid very extensively on Fridays, to enable the workers and their families to expend their earnings conveniently and judiciously. With the progress, therefore, of the industry of Manchester, opportunities are afforded to the superior and working classes for recreative amusements, whereby their physical health may be invigorated, and, by the increase of libraries and instructive institutions, their mental faculties may be improved and developed.

Many new manufactures have been introduced into the neighbourhood of Manchester. The production of the textile fabrics in all their combinations of cotton, of silk, of woollen, and of flax, has greatly increased; and mixed materials in various goods have thus formed new fields for industry, and called forth the exercise of skill, taste, and ingenuity in results alike fanciful and attractive. Messrs Houldsworth have, with great advantage, skilfully applied mechanical embroidery to all the fabrications of the manufacturer. Glass-works have been established; and the conversion of iron into steel has become an important addition to the now multifarious sources of employment in this district. With these increased sources of employment, labour finds a steady market. But from the cotton industry chiefly flow the profits which recompense the toil of the labourer, and enhance the capital of the manufacturer and merchant. Manchester is unquestionably the metropolis of this vast industry. Not only in this increasing city are there extensive spinning mills and manufactories, but it has become the general market for almost the whole trade; palatial structures of great magnitude have been erected in it as warehouses; manufacturers have entered largely into mercantile operations; and the merchants finding the mere freighting of vessels inadequate to their business, have in many instances become shipowners. To illustrate the progress of this trade, the following tables, showing the imports and consumption of cotton, have been prepared:—

Table of Imports of Cotton into the United Kingdom.

	1806.	1816.	1826.	1836.	1846.	1856.
From United States of America..........Bags	124,939	166,077	395,852	764,707	932,000	1,758,300
... Brazil, or South America	51,934	123,450	55,590	148,715	84,000	121,600
... Egypt	......	......	47,621	34,953	59,600	113,000
... East Indies	7,787	30,670	64,699	219,493	49,500	463,000
... West Indies and other Colonies... ...	77,978	49,235	18,188	33,506	9,000	11,400
Total Bags for each year...........	261,638	369,432	581,950	1,201,374	1,134,100	2,467,300

Table of Consumption of Cotton in the United Kingdom.

Of each kind in the years—	1806.	1816.	1826.	1836.	1846.	1856.
	Approximate.					
Of American..............................Bags	120,000	209,352	356,980	747,240	1,280,396	1,657,132
Brazilian	50,000	82,628	61,776	130,416	106,496	145,496
Egyptian............................... ...	......	......	50,700	33,488	69,576	127,764
East Indian	7,000	10,764	25,428	77,584	113,828	269,412
West Indian, &c.	75,000	34,112	16,016	22,776	15,600	13,520
Total Bags for each year...........	252,000	336,856	510,900	1,011,504	1,585,896	2,213,324
Per week of every kind............	4,846	6,478	9,825	19,452	30,498	42,563

The following valuable table will show manufacturing progress and results:—

Estimate of the Sums accruing to the Trade in Cotton Manufactures during the years from 1847 *to* 1856, *to pay for expenses of Fuel, Machinery, Drugs for Dyeing, Printing, Bleaching; Interest of Capital, and every kind of Wages, Profits, &c.,—after deducting the Actual Cost of the Raw Material.*

	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Cotton consumed in Great Britain..................	421,385,238	591,595,083	626,710,160	584,000,000	648,408,150	751,000,000	734,623,000	780,000,000	836,000,000	920,000,000
Waste in Spinning this, 1¾ oz. per lb.................	46,089,038	64,705,683	68,546,460	63,875,000	70,919,650	82,140,000	80,349,000	85,312,500	91,437,000	100,625,000
Production of Yarns....................................	375,296,200	526,889,400	558,163,700	520,125,000	577,488,500	668,860,000	654,274,000	694,687,500	744,563,000	819,375,000
Disposed of as follows:—	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Exported in Yarns and Thread..........................	119,422,254	131,674,230	153,761,000	123,977,000	129,849,000	133,301,864	136,666,000	133,764,100	142,715,500	174,619,900
Exported Manufactured Goods reduced into weight of Yarn..............................	191,969,597	204,852,157	256,260,000	222,956,000	255,689,000	262,585,498	285,116,500	319,383,700	358,578,000	406,206,700
Consumed at home and not otherwise enumerated	63,904,349	190,363,013	148,142,700	173,192,000	191,950,500	272,972,638	232,491,500	241,539,700	243,269,500	238,548,400
As above..	375,296,200	526,889,400	558,163,700	520,125,000	577,488,500	668,860,000	654,274,000	694,687,500	744,563,000	819,375,000

	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.
	at 6⅛ ⅌ ℔ L.	at 4$\frac{1}{16}$ ⅌ ℔ L.	at 4$\frac{11}{12}$ ⅌ ℔ L.	at 7$\frac{2}{9}$ ⅌ ℔ L.	at 5¾ ⅌ ℔ L.	at 5⅜ ⅌ ℔ L.	at 6 ⅌ ℔ L.	at 5$\frac{3}{5}$ ⅌ ℔ L.	at 5⅔ ⅌ ℔ L.	at 6¼ ⅌ ℔ L.
Average cost of Cotton each year.........................	10,754,100	10,014,000	12,838,850	17,574,000	15,534,800	16,819,300	18,365,000	18,200,000	19,739,000	23,958,000
Declared value of exports, as per published statements.	L.	L.	L.	L.	L.	L.	L.	L.	L.	L.
Of Thread and Yarns......................................	17,882,000	5,957,000	7,129,000	6,820,000	7,084,700	7,161,700	7,449,50	7,216,200	7,785,900	8,652,000
,, Manufactured Goods...................................	17,717,000	17,382,000	19,761,000	21,432,000	22,994,300	22,795,300	25,259,80	24,428,000	27,025,900	29,632,000
Estimated home consumption in the same proportion as the declared value of the exported goods, plus ⅓	7,863,000	21,537,000	15,230,000	22,186,000	23,013,000	31,594,000	24,040,000	24,632,000	24,446,000	23,200,000
Total value of production.................................	43,462,000	44,876,000	42,120,000	50,438,000	53,092,000	61,551,000	56,749,300	56,276,200	59,257,800	61,484,000
Deduct the cost of Cotton as above......................	10,754,100	10,014,000	12,838,850	17,574,000	15,534,800	16,819,300	18,365,000	18,200,000	19,739,000	23,958,000
Sums remaining to be distributed as stated above	32,707,900	34,862,000	29,281,150	32,864,000	37,557,200	44,731,700	38,384,300	38,076,200	39,518,800	37,526,000

Of the exact extent of the cotton industry in all its branches no statistics exist. From returns made to government, and from the computations of experienced cotton spinners, the number of spindles in mule and throstle machinery cannot be fewer than 28,000,000; to prepare for which an immense number of scutchers, carding engines, bobbin and fly frames, and other auxiliary machines, are indispensable. The number of weaving looms, by hand and power, is beyond the means of estimation; but the spinning and weaving machines give no idea of the supplemental machinery, of the bleaching, printing, and dyeing works, and other aids of this important trade. In addition to the mills, steam-engines, and mechanism employed, there exist multitudes of cottages and dwellings connected with those establishments. And again, beyond these, the vast warehouses containing manufacturing stores, and those to receive and dispose of finished goods, represent in their occupied state an immense investment. But in approximating to an estimate of the fixed and floating capital invested in this now national industry, the shipping required to convey to our shores the requisite raw materials, and that necessary for dispersing the manufactured products, should be remembered. The working of mines, the traffic in minerals, and the banking operations for this trade, are important items; and the actual employment of mercantile capital will altogether indicate a sum of extraordinary magnitude. So that, in naming one hundred millions of pounds sterling as the total amount of fixed and floating capital employed in connection with the cotton manufacture, the truth will not be exceeded.

The trade and commerce of Manchester and the neighbourhood have been much promoted by the valuable services of the Chamber of Commerce. This institution was founded in 1820, and from its commencement has been a consistent opponent of the corn laws, and of monopolies of every kind. It was the first public body to repudiate protection for manufactures—to call for the abolition of every species of differential duties, and for the repeal of the navigation laws. All questions, however, of a purely political complexion, are strictly forbidden to be entertained, either at the meetings of the board of directors, or at a general meeting of the members. The steady and firm course which it has pursued has earned for it a respect and consideration not surpassed—probably not equalled—by any similar association in existence. Its proceedings attract attention in every commercial community throughout the world. Previously to the repeal of the corn laws the chamber had contended for their entire abolition; but there arose another association, named the Commercial Association, which pleaded only for a fixed duty upon foreign corn, though now happily both these institutions are guided by free-trade principles.

The Anti-Corn-Law League, which so essentially contributed to the recognition of free trade as the basis of domestic and international commercial legislation, was called into existence in this city in 1838, and amongst its early, constant, and most distinguished promoters, have been Sir John Bowring, Richard Cobden, John Bright, George Wilson, J. B. Smith, C. P. Villiers, and the late Sir William Molesworth; but, as a confederation, it ramified over the whole United Kingdom. For the single purpose of overthrowing all obstacles to the free import of corn, its council wisely rejected all overtures which would have diverted its exertions to political or other objects; and greatly to the honour and sagacity of the leaders of the council, the propositions made by the Chartists to induce a common organization to be formed between these two bodies, to procure radical changes in the constitution of the country, were not entertained. At length, in 1846, the legislature, either from truthful conviction of the injustice of those laws, or impelled by the fear of denying the almost unanimous call of the people, finally erased them and the principle of protection from the statutes of the realm. To that eminent statesman, Sir Robert Peel, the people of this manufacturing district, and of the United Kingdom, owe a debt of gratitude for the patriotism and courage which he evinced in assisting to annihilate class legislation; nor will this example be lost upon those who direct the destinies of other nations. With the fundamental changes thus effected in the economical laws of this country, the people at large have enjoyed more prosperity than at any previous time; they have become more attached to their institutions, and their loyalty to their sovereign has never before been exceeded.

Happily, with the extension of trade and commerce in Manchester, there has been developed a desire to promote educational, social, physical, and sanitary improvements. Many attempts have originated here to obtain a national system of elementary instruction for the young, but hitherto without success. The diminution in the hours of labour generally affords more time for self-improvement and kindly intercourse amongst work-people. By the establishment of public parks—the gifts of the rich to the poor—such as the Queen's, Peel's, and Philip's, healthful exercise is more amply afforded, and a link of sympathy between the people and their benefactors is hereby secured. A sanitary association has also been formed.

Grateful for the services of the Duke of Wellington and of Sir Robert Peel, the inhabitants of Manchester have erected to their memories suitable statues, which are placed in the area of the Royal Infirmary. The former is represented by the sculptor Noble as a warrior and senator; and the latter by Calder Marshall as a statesman and patron of the arts of life. As if to prove that commerce still exists in alliance with the fine arts, there was opened in Manchester, in May 1857, an exhibition of the treasures of art, procured exclusively from the resources of the United Kingdom. The Queen and Prince Albert have graciously and generously contributed many of their gems of art, and personally have expressed their warmest solicitude for the success of the exhibition. Patrician and plebeian owners of works of art have rivalled each other in the richness and rarity of their contributions; and a more refining, elevating, and instructive source of gratification cannot be conceived than will probably be afforded by this unique gathering of the curious and beautiful stores of art.

The population of Manchester has had a most amazing growth. The town comprehends several townships, viz., Manchester, Chorlton-upon-Medlock, Cheetham, Ardwick, Hulme, Newton, Harpurhey, Bradford, and Beswick, which form the borough of Manchester; Salford, Pendleton, and Broughton, that of Salford; but they are physically, as well as politically and commercially, *one* town, though having separate local governments. Of the townships of Manchester and Salford, the population was as follows at the decennial periods:—

	Manchester.	Salford.
1801	70,409	13,611
1811	79,459	19,114
1821	108,016	25,772
1831	142,026	40,786
1841	192,403	70,224
1851	228,437	87,514

It is calculated that the population of Manchester, Salford, and their districts, is now not less than 500,000.

The township of Chorlton-upon-Medlock, now filled with factories, was not many years since a desert, and the population has sprung up in a way wholly unprecedented. It was, in 1801, 675 persons; in 1811, 2581; in 1821, 8209; in 1831, 20,569; in 1841, 77,107; and in 1851, 123,806. Property has increased in the same rapid ratio. In 1815 the annual value was L.19,830; in 1835 it was L.58,844. A similar augmentation has taken place in other townships. In Manchester in 1815 the annual value of property was only L.308,634; in 1835 it was L.573,085; and in 1856, L.891,228. In Salford it was, in 1815, L.49,048; in 1835, L.114,769; and in 1856, L.201,042. In Broughton (a township without manufactures) the annual value of lands and buildings was, in 1815, only L.5082; in 1835, L.21,303. In Cheetham (also a township containing only private residences) the value was, in 1815, L.8524; in 1835, L.28,541; and since, these townships have proportionately increased.

Manchester ranks as the first manufacturing town in the empire, and in population it is second only to London. The county is divided into several hundreds, Manchester being situated in the centre of that of Salford, in which there has been an immense increase of population within the present century. The total annual value of property in Salford hundred was, in 1815, L.918,397, and in 1829, L.1,554,314. Of these amounts, L.488,053 at the former period, and L.751,200 at the latter, were comprised in the parish of Manchester, which is divided into thirty-two parishes.

In 1848 Manchester became a bishopric, and Dr James Prince Lee was nominated the first bishop. Under this learned and tolerant divine the church establishment has been judiciously fostered, and its usefulness has been greatly increased.

Manchester, as an old parish, has a parish church, said to have been erected by a Lord Delaware in 1422, out of two old churches built in 1300. It is a fine Gothic structure, 216 feet in length from east to west, and 120 feet in breadth, with a handsome tower. It is richly ornamented in the cathedral style, having on the exterior numerous grotesque figures projecting from the roof, in the taste of the age in which it was built. It has of late years been extensively repaired and beautified in conformity with the original design, and affords accommodation, by its great proportion of free seats, to a numerous congregation. It was made collegiate by the founder, who amply endowed it; and, by the increased value of the property, it became a rich ecclesiastical establishment, with a warden, four fellows, and two chaplains; but since the creation of the see of Manchester, the warden and fellows have been substituted by a dean and four canons, the latter now having each the care of a district church. The only churches more than seventy years old are,—St Ann's, in the square of that name, consecrated in 1765; and St John's, in Byrom Street, opened in 1769. As the town has grown, more churches have been built, and others are now being built. The number of those edifices in which the established forms of worship are observed is now very considerable. They are all handsome, some of them elegant structures, and all in the interior are neatly and appropriately finished. As in other manufacturing towns, the number of those who dissent from the Established Church is very considerable. There are six congregations belonging to the Presbyterian Church, two to the United Presbyterian, and one to the Scotch Church; but the largest division is the adherents to the Roman Catholic Church, consisting for the most part of Irish immigrants employed in the lowest kinds of labour. They have seven places of worship, one of them, in Granby Row, opened in 1820, very handsome and costly, in the Gothic style; and in Salford has been erected a most splendid ecclesiastical structure, which, in truth, may be regarded as a Roman Catholic cathedral. There are about thirty chapels belonging to Wesleyan Methodists of different shades of opinion; the Independents have nineteen places of worship, the Baptists eight, the Unitarians four; and there are several belonging to other smaller sects.

As to the religion of the inhabitants, there are other ascertained facts of a more general nature. The church accommodation in Manchester and Salford consists of about 40,000 sittings, exclusively of the Scotch Kirk; that in the Wesleyan Methodist chapels of about 10,000; Roman Catholic and all other dissenting chapels of about 25,000 sittings. The Sunday schools in Manchester and Salford attached to the various religious communities, and the total numbers instructed by each, are as follows:—

Sunday-Schools in Manchester and Salford.

Denominations.	Number of Scholars.		Total.
	Manchester.	Salford.	
Church of England	18,029	6,716	24,745
Independents	8,443	3,772	12,215
Wesleyans	8,746	2,314	11,060
Wesleyan Association	2,598	856	3,454
Primitive Methodists	1,361	750	2,111
Baptists	1,951	750	2,701
New Connexion	1,160	273	1,433
Presbyterians	1,098	163	1,261
Unitarians	1,064	...	1,064
Bible Christians	298	...	298
Scotch Church	251	...	251
Congregational Methodists	287	...	287
Welsh Calvinistic	300	...	300
Roman Catholics	9,650	2,500	12,150
Total	55,236	17,894	73,130

After London, Liverpool, and Dublin, the payments to the post-office in Manchester exceed those of any town in the kingdom. They were for the three years, 1832, 1833, and 1834, respectively, as follows:—L.53,510, 8s. 4d., L.56,287, 16s. 11d., and L.60,621, 12s. 6d. Since that period, the beneficial change effected in the postal arrangements of the United Kingdom, by the introduction of a universal penny postage, has rendered the money receipts of this office no adequate comparative standard for recording the progress of the correspondence generally resulting from the vast increase of trade and commerce in this city; yet in 1856 postage stamps sold at the Manchester post-office, and postages, &c., paid, amounted to L.75,043. The money-orders received and paid at this office in the same year amounted to L.570,506, 15s. 4d.,—thus proving the immense advantage of this banking auxiliary to the poor, as well as to all other classes of the community.

The state of the poor in Manchester, and throughout Lancashire generally, is remarkably comfortable and prosperous. A reference to the returns of the expenditure of poor's rate in Lancashire, and other counties, places this fact quite beyond dispute:—

COUNTIES.	1801.			1811.			1821.			1831.			1841.			1851.		
	Expenditure for Maintenance of Poor	Proportion to Population.		Expenditure for Maintenance of Poor	Proportion to Population.		Expenditure for Maintenance of Poor	Proportion to Population.		Expenditure for Maintenance of Poor	Proportion to Population.		Expenditure for Maintenance of Poor	Proportion to Population.		Expenditure for Maintenance of Poor	Proportion to Population.	
	L.	s.	d.	L.	s.	d.	L.	s.	d	L.	s.	d.	L.	s.	d.	L.	s.	d.
Lancashire	148,282	4	4	306,797	7	4	249,585	4	8	293,226	4	4	262,227	3	1¾	365,767	3	7
Cheshire	66,627	6	11	114,370	10	0	104,081	7	8	103,572	6	2	77,698	3	11	79,442	3	5¾
Derbyshire	54,459	6	9	93,963	10	1	84,756	8	1	78,717	6	7	55,238	4	0½	49,874	3	4¼
Kent	206,508	13	5	317,990	17	0	320.711	17	4	345,512	14	5	208,786	7	7	187,204	6	0¾
Middlesex	349,200	8	6	502,967	10	6	582,055	10	2	681,567	10	0	435,606	5	6¼	530,062	5	7¼
Staffordshire	83,411	6	11	124,765	8	5	133,702	7	10	132,887	6	5	95,242	3	8	101,356	3	4
Yorkshire, East.	41,388	7	5	83,752	10	4	97,522	10	6	100,976	9	10	68,182	6	11¾	65,127	5	10½
North	48,702	6	1	70,860	8	4	82,638	8	9	83,931	8	9	58,308	5	8	56,425	5	3
West	186,469	6	7	328,113	10	0	273,301	6	9	274,586	5	7	245,676	4	2½	243,432	3	8

Manchester.

In the township of Manchester, the expenditure exclusively for the poor (deducting the heavy payments to hundred and county rates, and for constables' accounts), was,—

	Per Head on Population.		Per Head On Population.
In 1800–1 …………	6s. 10¾d.	In 1830–31 …………	4s. 3¾d.
In 1811–12 …………	6s. 6¼d.	In 1856 …………	3s. 3½d.
In 1820–21 …………	5s. 3d.		

And in this last year the in-door paupers cost 2s. 3d. per head, whilst the out-door had relief to the amount of 1s. 2½d. for each person so relieved.

The population is taken in the month of April; and as the making up of overseers' accounts takes place on the 25th of March, it was thought better in each instance to take the period nearest to the date of the census, which will account for the years being put in this way.

In the township of Chorlton-on Medlock, almost exclusively a manufacturing suburb, the expenditure has been,—

	Outlay for the Poor.	Proportion to the Population.
In 1826–27…………………	L.317 9 2½	……2s. 8¼d.
In 1830–31…………………	711 12 1	
In 1834–35…………………	945 5 8	

A striking and most important difference appeared in the expenditure of another township (Broughton), in which were few or no manufactures to employ the poor; showing that the poor rates fell much heavier on an agricultural than on a manufacturing population:—

	Outlay for the Poor.	Total Expenditure.	Proportion of the former to the Population.
1827…………	L.444 13 9	L.901 11 9½	…… 4s. 0¼d.
1831…………	320 1 4	856 2 6	
1835…………	186 12 10	796 12 11½	

In connection with these statistics, which are intended to communicate, in as concise a form as possible, a correct view of the condition of the people of the principal manufacturing town of Great Britain, it is important to exhibit some data as to the state of crime in the district; and the following table affords that information in an authentic form.

Statement of the Number of Prisoners Tried and Convicted at the New Bailey Court-House, Salford, in the following Years:—

Years.	Male Felons.	Convicted.	Female. Felons.	Convicted.	Misdemeanours.	Convicted.	Total. Tried.
1794	92	62	41	17	17	12	150
1800	164	97	93	64	184	44	441
1805	80	60	63	42	109	36	252
1810	114	92	64	56	55	48	233
1815	254	194	110	101	133	126	497
1820	589	537	136	122	181	164	906
1825	677	589	223	212	93	65	993
1830	599	509	151	119	92	80	842
1835	723	608	213	187	123	73	1059
1840	1157	956	322	272	191	132	1670
1841	1328	1073	384	265	280	145	1992
1842	1288	1053	331	276	402	236	2021
1843	945	750	323	258	170	117	1438
1844	862	671	302	234	162	99	1326
1845	843	617	305	227	127	81	1275
1846	834	605	330	247	127	85	1291
1847	1007	780	379	302	165	99	1551
1848	1061	804	318	246	164	117	1543
1849	854	707	279	224	188	133	1321
1850	624	518	264	212	92	78	980
1851	463	379	179	152	62	53	704
1852	533	438	165	127	87	55	785
1853	467	392	188	154	85	69	740
1854	534	430	231	172	105	73	870
1855	548	445	252	233	111	81	911
1856	431	339	145	113	73	58	649

Manchester.

Total committed for felony since 1840 …………	18,476	21,067.
… committed for misdemeanours since 1840	2,591	
… convicted for felony since 1840 …………	14,671	16,382.
… convicted for misdemeanours since 1840..	17,11	

Return of the Manchester Borough Court.

Years.	Taken into Custody.		Summarily Convicted.		Tried and Convicted.		Committed for Trial.		Discharged.	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
1840	8,647	3,770	1,900	643	538	133	620	176	5,589	2,818
1841	9,925	3,420	1,661	477	645	179	763	236	6,856	2,528
1842	9,726	4,075	2,218	739	669	149	854	201	5,985	2,986
1843	8,489	3,658	2,163	818	432	158	541	217	5,353	2,465
1844	7,535	3,167	2,955	1,006	398	142	503	188	3,679	1,831
1845	6,913	2,722	3,977	1,140	379	156	482	185	2,075	1,241
1846	5,382	2,247	2,905	890	360	167	458	200	1,659	990
1847	4,485	2,102	2,149	831	483	171	604	229	1,249	871
1848	4,435	1,842	2,095	790	511	135	643	182	1,186	735
1849	3,331	1,356	1,733	578	389	138	472	178	737	462
1850	3,280	1,298	1,625	433	416	178	511	229	728	458
1851	3,582	1,308	1,742	434	495	227	608	272	737	375
1852	3,841	1,325	2,039	455	510	220	632	257	660	393
1853	3,928	1,434	2,122	505	423	200	545	249	838	480
1854	4,366	1,589	2,133	451	558	247	671	284	1,004	607
1855	4,380	1,674	2,435	642	504	244	643	293	798	495
9 mos. 1856	3,172	1,298	1,779	593	389	116	467	168	537	421
	95,417	39,285	37,631	11,425	8099	2960	10,017	3774	39,670	20,156

Taken into custody,	133,702	of which 49,056 were summarily convicted.
Discharged……….	59,826	… 11,059 were tried and convicted.
	73,876	… 13,761 were committed for trial.

The towns of Manchester and Salford consist of two boroughs, and are governed by two mayors and a number of aldermen and councillors. The two corporations have distinct municipal powers; but sometimes they co-operate for a great and common object. Manchester has recently supplied itself with excellent water from Woodhead in Derbyshire, and Salford participates in the great advantage of the acquisition. Manchester possesses large gas-works, which are important, inasmuch as the profits accruing from them are expended upon those improvements which tend so much to the health, the comfort, and the ornament of a densely peopled town.

The gigantic undertakings of the celebrated Duke of Bridgewater, who, and his engineer Brindley, may without exaggeration be styled the parents of canal navigation in England, had their centre in Manchester. In succeeding years the example so nobly set was rapidly followed, and Manchester has the advantage of a connection, as direct as canal and river navigation conjoined can afford, with Liverpool, Hull, Goole, London, Lancaster, and indeed all the great seaports and inland commercial towns. It is remarkable that this district should have been the first to manifest the immense importance of railway communication. The history of the Liverpool and Manchester Railway, which was opened in 1830, is familiar to every one; and now (1856) Manchester has complete communication by railways with every part of the United Kingdom.

Manchester has been the birthplace, or abode, or central point of action, of many eminent men. In remoter times the names of Hugh Oldham, Bradford, Booker, Dee (the astrologer), Whitaker (the historian), Byrom (a poet, and the inventor of a system of short-hand), Worthington, Percival, Ogden, Hugh Manchester, Humphrey Chetham, Heyrick, Lord Delamere, Bancroft, Barlow, and Crabtree, hold a prominent place in the history of the town and its connections. Amongst the illustrious of modern days, the commercial metropolis may claim as her own the eccentric Duke of Bridgewater. Mr Thomas Henry, though not born in Manchester, spent his life there; and his attainments as a chemist were brought into beneficial exercise upon the cotton manufacture of the country, in the discovery of most important improvements in the art of dyeing, through the operation of mordants, and by simplifying and applying practically to manufactures the discovery of M. Berthollet in regard to the qualities of oxymuriatic acid, a discovery by which the time occupied in the process of bleaching calicoes has been reduced from days to hours. The first Sir Robert Peel, though born near Blackburn, and a resident of Bury, had his manufacturing establishment in Manchester, and was probably the most extensive manufacturer of his day, excepting perhaps Sir Richard Arkwright. Dr Dalton also, though born in Cumberland, spent his life from the age of twenty-six or thereabouts in Manchester, whither he went originally from Kendal on his appointment to the post of professor of mathematics and natural philosophy at the Manchester New College,—an institution which was subsequently moved to York, but has found a resting-place in Manchester again. The doctor was many years president of the Manchester Literary and Philosophical Society through which many of his most valued discoveries have been communicated to the world. He died in 1844; and now in the infirmary area there is a beautiful bronze statue after Chantrey, to commemorate his discoveries and the esteem in which he was held by his friends and fellow-citizens.

The municipal government of the township of Manchester was formerly committed to a boroughreeve and two constables, who were elected at the court-leet of the lord of the manor, Sir Oswald Mosley, Bart. The boroughreeve exercised the power, without enjoying any of the external distinctions, usually pertaining to a mayor. There was an effective police establishment, under the direction of 240 commissioners elected by the occupants of tenements of a certain annual value; but the local government under the existing corporation is more satisfactory and efficient.

Manchester has a considerable number of associations for the cultivation of science and literature, and the promotion of education. The Royal Manchester Institution ranks first in importance, the inhabitants having expended about L.30,000 in the erection of a noble edifice for periodical exhibitions of paintings, the delivery of lectures, &c., leaving themselves unhappily almost without the means of fulfilling the purposes for which the building was raised. In 1825 a Mechanics' Institution was opened under the presidency of Sir Benjamin Heywood, Bart.,—its area being 738 yards, and the cost L.7000; and 25,000 students have derived the advantage afforded by this institution. Lord Morpeth distributed the prizes of 1833, and Lord Brougham was a visitor in 1835. This institution not being large enough, nor its rooms commodious, a new building was erected in 1855 to supersede the old one, and which was opened by an exhibition of great interest in 1856, under the patronage of Lord Palmerston.

The presidents of the Mechanics' Institution have been, —Sir Benjamin Heywood, Richard Cobden, H. Day, the Right Honourable the Earl of Ellesmere, J. A. Turner; and Oliver Heywood, the son of the first president, is the chairman at the present time (1857). Among the palpable benefits derived from this invaluable institution, the teaching of young females has been of conspicuous advantage. The area of the new building is 942 yards; and the cost of ground, building, and furnishing the several rooms for the use of the members, L.24,000; in diminution of which, there will arise the proceeds of the old institution, valued at, for ground and building, L.7000. The opening exhibition will leave a clear profit of L.4300. It has been visited by 300,000 persons.

The numbers attending the several classes (Christmas 1856) were as follows:—

Female Day Classes.

Morning and afternoon classes for reading, writing, arithmetic, grammar, history, &c.	155
French	25
Pianoforte	39
Dancing	63
Vocal music	17
Dress-making	12
Drawing	26
Wax modelling	5
Total number	342

Male Evening Classes.

Reading, writing, arithmetic, &c.	220
Grammar	82
Geography	44
Mechanical and architectural drawing	130
Landscape and figure drawing	32
Dancing	71
French language	91
German	28
Mathematics	43
Commercial writing	42
Total number	783

There were also, at the above date, 148 members paying 21s. per annum, but not taking advantage of the classes, and 150 life members, having paid in past years L.10, 10s. each.

Very many respectable men,—civil engineers, working mechanical engineers, managers of cotton mills, surveyors, and men holding important confidential offices as cashiers, corresponding clerks, &c., were educated in the classes of the institution.

An excellent natural history society is in a flourishing state; the town boasts a concert hall having an income of L.3000 per annum; there are two schools of medicine, the elder of which (the Pine Street) has attained to considerable celebrity, and which obtained the patronage of King William IV.; and amongst the numerous public libraries is one to which free access is afforded, and which has a large and most valuable collection of books, ancient and modern. This is the library attached to that antique structure, Chetham's Hospital, or the College (now so called), an institution founded two centuries ago by the man whose name it bears, for the maintenance, education, and apprenticing of a number of boys, the offspring of poor parents. Very lately, however, another free library has been established by voluntary subscriptions, chiefly obtained by Sir John Potter, and it is maintained by a municipal rate collected under the act supported by Mr Ewart, M.P. In Salford, also, under the same act of Parliament, has been provided a museum and library, the access to which is likewise free. The Grammar School is another of the ancient foundations which do honour to the town; of late years its funds have so far increased as in 1855 to justify the erection of a second school, in which a course of general education may be gratuitously obtained, whilst the parent building is still devoted to the diffusion of classical knowledge. The school has the advantage of several "exhibitions." The inquiry into the public charities of England includes a very large return of charitable bequests still existent within the hundred of Salford, and of these Manchester has its full share. The town also supports, with a most liberal hand, medical institutions for the cure of almost every disease incident to humanity. At the head of these stands the Royal Infirmary, established in 1752. There are also a Ladies' Jubilee charity, a school for the deaf and dumb, and a blind asylum, which had its foundation in a bequest of L.40,000, made several years ago by Mr Henshaw, a wealthy inhabitant of Oldham; the condition of its application to that benevolent object being, that no part of the sum should be expended in the erection or furnishing of the building, but that the latter should be provided by the inhabitants. After considerable delay, about L.9000 was subscribed, and the asylum has been erected in the outskirts of the city. Other institutions for the relief of the afflicted and the distressed, for the promotion of education and the spread of religion, abound in Manchester, which indeed exhibits a prominent example of the almost profuse expenditure of wealth, hardly acquired, for philanthropic and useful purposes. (T. B—Y.)

MANCHESTER, a town in Hillsborough county, state of New Hampshire, North America, is situated on the left bank of the Merrimack River, 18 miles S.S.E. of Concord, and 59 miles N.W. from Boston. The town is built on a plain at the height of 90 feet above the river, and is regularly laid out. The principal street is wide, and is upwards of a mile in length, parallel to the river. There are four public squares in different parts of the town, some of which are handsomely ornamented. The houses are mostly of brick, but there are many wooden houses, some of which are tasteful structures. The slope from the plateau on which the town stands to the river is occupied by the mills and houses of the workmen. Manchester possesses twelve churches belonging to different denominations; and the educational establishments consist of a high school, two grammar schools, besides others of an inferior class. Manchester has risen into importance quite recently by reason of the water power, which affords great advantages to the manufactories here. Not far from the town the river has a fall of 54 feet in a mile, which is taken advantage of by means of dams and canals, so that it turns many thousand spindles. The town is chiefly remarkable for its manufactures. One company possess four mills, which give employment to 2500 hands, and weave daily 65,000 yards of various stuffs. There are also at Manchester print-works, paper-mills, machine-shops, foundries, and other establishments. In the year 1839 this place only contained fifty inhabitants, but it has rapidly increased since that time. Manchester received its charter in 1846. Pop. (1850) 13,932, (1853) 20,000.

MANCHOORIA, or MANDSHURIA, a large district in the N.E. of Asia, constituting a government of the Chinese Empire, and bounded on the N. by Siberia, on the E. by the Gulf of Tartary and the Sea of Japan, on the S. by Corea and the Yellow Sea, and on the W. by Mongolia. It lies between N. Lat. 42. and 58., and E. Long. 120. and 142., and has an area of between 650,000 and 780,000 square miles. This region is almost entirely surrounded by mountains. The highest of these ranges is the Khing-khan-ula, which separates this district from the table-lands of Central Asia. Its highest summit, Pecha, is more than 15,000 feet above the level of the sea, and is situated near the southern extremity of the range. On the N., Manchooria is separated from Siberia by a lower range, called by the Russians Yablonoi Khrebet, and by the Chinese, Khing-khan Tugwick. Along the eastern coast there extends a very steep ridge, approaching in many places very near to the sea, and which rises to an elevation of 5000 feet. On the S., a prolongation of the Siolki range extends along the frontiers and joins the eastern chain; while the only part which is not surrounded by mountain barriers is towards the S.W., where there is a tract of country of an undulating and hilly character. The region included by these mountains presents towards the S. the appearance of a vast plain, chiefly sandy, but containing many grassy spots which afford good pasturage, and abounding in salt lakes. The northern part of Manchooria, on the other hand, is a country diversified with hills and valleys, almost entirely covered with forests. The country is watered by numerous rivers, of which the principal are,—the Amur and its tributaries, the Seja, the Songari, the Ussuri-ula, &c.; the Tumen-ula, and the Sira Muren, or Liao-ho. Of the soil and mineral resources of this region little is known, since it has never, except in the southern parts, been visited by European travellers; and we are left to the doubtful authority of the Chinese. Wheat, rye, barley, hemp, and cotton, are produced in considerable quantities; and the forests are composed of oak, lime, pine, birch, willow, maple, &c. Rhubarb is also found in considerable abundance, and forms one of the chief articles of export. The domestic animals of this country are for the most part the same as those of Central Asia, with the addition of the rein-deer, which inhabits the country to the N. of the Amur, and the camel, which is found to the S. of that river. Among the wild animals, sables, ermines, bears, wolves, and foxes are the most numerous; and the people are much occupied in hunting them and trading with their skins. The wild sheep and the wild ass are peculiar to this and the neighbouring countries. Tigers are said to occur in Manchooria. Fish and pearls abound in the rivers, and of the latter article the divers send a yearly tribute to the Emperor of China. The climate of Manchooria is cold, and the winters severe, owing to its geographical position and its elevation. The population, with the exception of some Mongolians, belong to a wide-spread race called Tunguses or Tungusians, one subdivision of which comprises the Mandshurs. The Tungusians proper are most numerous to the N. of the Amur, and they are also spread over a considerable portion of Siberia. Their manner of life is erratic; and they subsist chiefly by hunting and by their large herds of cattle. To the race of the Mandshurs the reigning family of the Chinese empire belongs. They began their incursions in 1610, and in the year 1662 they had made such progress as to set upon the throne a monarch of their own nation. The Tungusian language differs from the Mongolian, and though not supposed to have any connection with any other dialect, exhibits a remarkable similarity in many words and expressions to some of the languages of Western Europe; which is the more remarkable as this is the most easterly country in Asia. Manchooria is divided into the three provinces of Shin-king, Kirin, and Tsi-tsi-har, the first of which is governed in the same way as the rest of the Chinese empire; while the other two are under a military despotism. The capital is Kirinoola, or Ghirin-ula, though Moukden, which was formerly the metropolis, is still the most wealthy city; and the other most important towns are Saghalin-ula, Kin-chu, and Fung-whang-ching. An invasion was made into Manchooria by the Russians in the seventeenth century, but although they established themselves for forty years on the Amur, they were at last driven out by the Mandshurs. During the last ten years, however, they have again resumed their attempts, and have made incroachment in the north, having built a fort on the Amur, and several others on the sea-coast. One of these was unsuccessfully attacked by the British in 1855, and another was attacked by some American ships. The population of Manchooria is uncertain, the estimates varying from 2,000,000 to 4,500,000.

MANDAR, MICHEL PHILIPPE, better known under the name of *Théophile*, one of the most enthusiastic characters of the French revolution, was born at Marine in 1759, and studied at Juilly under his uncle J. F. Mandar, a priest of the Oratoire, author of several pleasing poems in Latin and French. Of an active disposition and an ardent imagination, young Mandar embraced the cause of the revolution with great warmth from the commencement, and was early distinguished as a revolutionary orator. When the Swiss regiments under Bezenval endeavoured to check the populace of Paris in their attempt to seize the arms deposited at the Hôtel des Invalides, on the attack of the Bastile, Mandar, at the greatest personal risk, succeeded by a dexterous stroke in persuading the Swiss commander to withdraw his troops, which facilitated the capture of that celebrated prison. Mandar's name, moreover, deserves honourable mention for the mild humanity which he displayed amidst the unscrupulous violence of many of his compeers. On the 3d September 1792, and during the massacres of that memorable month, Mandar, at a meeting in Danton's house, where the chiefs of the revolution sat in council, proposed and boldly stood out for the creation of a dictator to prevent the further effusion of blood, but had the misfortune to see mutual jealousy defeat his humane suggestion. Robespierre exclaimed, "*Garde-t'en bien, Brissot serait dictateur !*" Mandar survived the revolution, but refused office under the imperial government. He occupied his years of retirement with literature, and particularly with translations from the English. His works, political, historical, miscellaneous, and poetical, display great force of thought and energy of expression. He died at Paris in 1823.

MANDARA, an independent kingdom of Western Africa, situated to the south of Bornou. It is overlooked by the central range of the Mountains of the Moon, which attain their greatest elevation to the southward of this territory. Those parts of the mountains examined by Major Denham consist of enormous blocks of granite, both detached and reclining on each other, and presenting the most rugged faces and sides. The interstices and fissures appeared to be filled with a yellow quartzose earth, in which grow mosses and lichens, as well as trees of considerable size. At the base of these mountains, and also at a considerable elevation on their sides, are incumbent masses of decomposed fragments of primitive rocks, recompounded by a species of natural cement. A number of petrified shells were found confusedly mixed with fragments of granite, quartz, sand, and clay, and in some instances imbedded in the rocks. Mandara consists of a fine valley watered by several springs. Amongst the various specimens of the vegetable kingdom are numerous fig trees, and a tree bearing a white and fragrant blossom, resembling the seringi. This kingdom was formerly comprehended within the territory of the Sultan of Karowa, a country bordering upon it to the S.W., but which was wrested from the *kerdy* or pagan sovereign by the neighbouring Fellatahs. His son, however, recovered it from them, and succeeded in keeping possession of it, chiefly, it is said, in consequence of his having embraced the Mohammedan faith. The principal Mandara towns, eight in number, all stand in the valley. The inhabitants of these, as well as of the villages by which they are surrounded, profess Islamism; but the pagans are far more numerous, and their dwellings are seen everywhere in clusters on the sides, and even on the tops, of the hills which immediately overlook the capital. They hold the sultan in great dread, and occasionally propitiate his favour by presenting him with leopard-skins, honey, and slaves, as peace-offerings, besides asses and goats, with which their mountains abound. Mora, the capital of Mandara, is situated in N. Lat. 10. 58. 38., and E. Long. 13. 22., nearly facing the N., under a semicircular ridge of very picturesque mountains. These natural barriers form a strong rampart on every side but one, which, however, the sultan is able so to defend as to bid defiance to the attacks of the Fellatahs. When Major Denham visited this kingdom he found the sultan surrounded by about 500 horsemen, posted on a rising ground about a mile from Delow, the most northern town in Mandara. These soldiers were finely dressed in Soudan *tobes* of different colours (chiefly dark blue, and striped with yellow and red), *bornouses* of coarse scarlet cloth, and large turbans of white or dark-coloured cotton. Their horses were beautiful, being larger and more powerful than any in Bornou, and they were managed with great dexterity. The country to the extreme S. is inhabited by the Musgow people, a rude and savage race. During the visit of the traveller above named, he witnessed the arrival of an embassy of between twenty and thirty individuals of this tribe, mounted on horseback, and bringing 200 of their fellow-creatures, and fifty horses, besides other presents, to the sultan. They were covered only with the skin of a goat or leopard; and round the necks of each were long strings of the teeth of the enemies whom they had slain in battle. Teeth and pieces of bone were also suspended from the clotted locks of their hair, and their bodies were marked with red patches in various places. Dirkullah, a part of this mountain territory, is occupied by Fellatahs, who have their villages strongly fortified, and fight desperately with poisoned arrows, by means of which they on one occasion put to flight the whole force of Bornou and Mandara, though aided by a numerous and well-armed body of Arabs. They are now, however, kept in subjection by the Sultan of Mandara. The common people of this country paint their bodies, wrap themselves in the skins of wild beasts, and subsist chiefly upon fruits, honey, and the fish drawn from large lakes.

MANDAVEE, a large and fortified seaport of Hindustan, in the province of Cutch, situated on the Gulf of Cutch. It trades to a considerable extent with Bombay, Arabia, &c., and its chief articles of export consist of butter, grain, and cotton, for which it receives sugar, pepper, spices, raw silk, piece-goods, &c. E. Long. 69. 26., N. Lat. 22. 50.

MANDAVEE, in Hindustan, a town situated within the presidency of Bombay, and the principal place of a feudal dependency, which, on the demise of its native ruler in 1840, and the failure of heirs in the direct line, lapsed to the paramount power, and was subsequently annexed to the British dominions. It now forms part of the collectorate of Surat. The town is situated on the right bank of the Taptee, in Lat. 21. 11., Long. 73. 20.

MANDEVILLE, BERNARD DE, an author of considerable celebrity in his day, was born about the year 1670 at Dort in Holland. After studying physic at Leyden, where he took the degree of doctor in that faculty, Mandeville came over to England, and commenced practising his profession in London. His success as a physician was not great; but taking to writing, he succeeded in gaining a livelihood, and establishing for himself more than an ordinary share of notoriety. He published his first work in 1709—*The Virgin Unmasked, or Female Dialogues betwixt an Elderly Maiden Lady and her Niece on several Diverting Discourses on Love, Marriage, Memoirs, and Morals*, &c. The work is characterized by anything but delicacy; and whatever may have been Mandeville's design in writing it, no one will be inclined to regard it as calculated to promote female virtue and innocence. In 1711 he published a work, in three dialogues, full of pungent remarks on modern medical practice, entitled *A Treatise on the Hypochondriac and Hysteric Passions*. His short poem of *The Grumbling Hive, or Knaves turned Honest*, appeared in 1714, and was afterwards expanded and published in 1723, under the well-known title of the *Fable of the Bees, or Private Vices Public Benefits*. This work, erroneous as it is in its views of morals and society, is much superior to his first publication; and while written with apparent honesty and sincerity of purpose, it nevertheless exposed its author to no ordinary degree of obloquy, provoking answers and attacks on all sides, and was finally, together with the *London Journal*, a paper to which Mandeville contributed, denounced as immoral, and proscribed by the grand jury of Middlesex. He kept silent till 1728, when he published a second part of the *Fable of the Bees*, to illustrate the design and vindicate the intention of the first.

He published also, in 1720, *Free Thoughts on Religion, the Church, and National Happiness;* and in 1732, *An Inquiry into the Origin of Honour and the Usefulness of Christianity in War*, a work abounding in paradox. He died on the 21st January 1733, in his sixty-third year. Sir John Hawkins, in his *Life of Dr Johnson*, says, that Mandeville was partly supported by a pension from "some vulgar Dutch merchants," and was a frequent guest at the table of the first Earl of Macclesfield. *The Fable of the Bees*, as a satire on men and manners, is just and pleasant, betraying powers of shrewd, happy, subtle observation, by no means common; but as a theory of society and national happiness, it is altogether false and worthless, calculated—however its author might disallow such an inference—to lower the standard of morality, if not to encourage vice and irreligion.

It is his object to show that national greatness depends on the prevalence of fraud and luxury. We find no distinction in his system between luxury and vice; he indeed boldly contends that virtue and vice, and the feelings of moral approbation and disapprobation, have been infused into men by their several governments for the preservation of society, and the maintenance of their own power. Of the host of assailants who attacked Mandeville, the most distinguished were,—William Law, whose remarks on the *Fable of the Bees* have lately been republished, with an introductory essay by F. D. Maurice; Hutcheson, author of *An Inquiry into the Original of our Ideas of Beauty and Virtue;* and Bishop Berkeley in his *Alciphron, or the Minute Philosopher.*

MANDEVILLE, *Sir John de*, the first English prose writer, was born at St Alban's about the beginning of the fourteenth century. Sprung from a good family, he received a liberal education, and seems to have practised for some time as a physician. He set out on his travels in 1322, and repaired to the Holy Land. After serving successively under the Sultan of Egypt and the Khan of Cathay, and journeying through Tartary, Persia, Armenia, India, and other countries, he returned to England about 1355. Not long after this he began to write a narrative of his adventures, which he dedicated to Edward III. He is said to have died at Liège in 1372. Mandeville's work presents a singular mixture of fact and fable. Minutely and candidly he relates his own observations regarding the countries he visited and the men whom he met. With the same truthfulness, whenever an opportunity occurs, he copies descriptions of monsters from Pliny, accounts of miracles from legends, and fables from old romancers. His book, written originally in Latin, was translated by himself into French, and ultimately into English. The original manuscript of this last translation is in the Cotton Library. The best edition is that published under the title of *The Voiyage and Travaile of Ser John Maundeville, knight*, 8vo, London, 1725, and reprinted in 1839, "with an introduction, additional notes, and a glossary by J. O. Halliwell, Esq., F.S.A., F.R.A.S."

MANDING, or MANDINGO, a district in the W. of Africa, bounded on the N. by Fouladou, on the E. by Bambarra, on the S. by Gallonkadou, and on the W. by Gadou, lies between 10° and 14° N. Lat., and between 13° and 16° W. Long. This district is very mountainous, and contains the sources of the Senegal and Niger. The mountains abound in iron, and a considerable quantity of gold-dust is found in the rivers. The country is divided into a number of small aristocratic republics, each village with the territory around it being nearly independent of the rest. The principal of these subordinate states are,—Manding, Bambuk, Bondu, Dentilia, Salum, Barra, Wooly, Yarra, &c. The chief towns are,—Kamalia, the capital, inhabited partly by Mohammedans and partly by Kafirs, Sillidolloo, Kankaba, Dorita, &c. The inhabitants are dark, well-proportioned, and strong; in character, they are good-natured, inquisitive, credulous, and truthful, but are much addicted to thieving. They seldom attain to any great age; but they are not liable to many diseases. The dress of the men consists of a coat, trousers, and sandals, while the women wear pieces of cloth wrapped about their body. Their dwellings are huts built of clay and thatched with rushes. Polygamy is practised among the Mandingoes, but each wife lives in a separate hut. A collection of huts belonging to a single family is called a *surk*, and several of these surks compose a village or town. Weddings are celebrated among the Mandingoes with great festivities. They are fond of music, dancing, and poetry; and they have two classes of wandering bards, who are held in much esteem. The chief occupations of these tribes are agriculture, hunting, fishing, wool-spinning, &c. They also trade in gold, ivory, and slaves; and they are well acquainted with the interior of Africa. In religion they are partly Mohammedans and partly heathens. The *marabouts*, or Mohammedan priests, make long journeys for the purpose of trade, and they are in like manner visited by the priests of other countries. The Mandingoes have spread abroad from their original seat over all the banks of the Gambia, Senegal, and Niger, and they are the most numerous of all the tribes of Western Africa. Their language, which is the richest of all the Negro dialects, is written in Arabic characters, and may be considered the most widely spread, and the most important in a commercial point of view, of all those spoken in Africa.

MANES. See MANICHEISM.

MANETHO, *the Sebennyte*, an Egyptian priest and historian, who flourished under the first Ptolemy, and probably the second also. He wrote a history of Egypt of which an epitome and some fragments remain, and, apparently, at least one other book. The epitome is given by Syncellus from the chronological works of Julius Africanus and Eusebius, of the latter of which there is extant an Armenian version. It is a list of thirty-one dynasties, with the number of kings in each, and generally their names, and with some historical events not always from the original work. The two principal fragments are preserved by Josephus (c. *Apion.*). The epitome does not contain any distinct statement of the complete duration of the dynasties. Such a statement is given by Syncellus, but there is strong reason to think it spurious. The dynasties are generally held to have been partly contemporaneous: hence different arrangements (for which see art. EGYPT). Manetho's accuracy is established by the agreement of the monuments; but much discredit was formerly cast on him by the fraud of an early impostor, now called "Pseudo-Manetho," who wrote the chronological *Book of Sothis*, apparently the groundwork of several false chronologies. Other forgeries seem to have been ascribed to the true Manetho. The extant *Apotelesmatica* may, however, be by a later person of the same name. The best editions of Manetho's remains are in Cory's *Ancient Fragments* (second edition),—nearly complete, but faulty in criticism; in Bunsen's *Egypt's Place*,—a better text, but defaced by some conjectural readings; and in the *Fragmenta Historicorum Græcorum* (Didot), where the arrangement is bad. (R. S. P.)

MANFREDI, *King of the Two Sicilies*, a natural son of the Emperor Frederick II. and of a Lombard lady, was born about 1234. His father dying in 1252, bequeathed to him the principality of Tarentum, and appointed him regent during the absence of his brother Conrad IV. No sooner had Manfredi begun to rule, than the province of Apulia, instigated by Pope Innocent IV., rose in open insurrection. With promptness and vigour he suppressed the rebels; and in the same year in which his government had commenced, delivered into his brother's hands an undisputed sovereignty. He had now become a favourite with the people, but from that very circumstance he was disliked by his brother, and removed from all share in the administration. Yet, in 1254, when the king died, leaving his crown to his infant son Conrad, then in Germany, Manfredi was once more called to the regency. His enjoyment, however, of this dignity was soon interrupted by the inveterate foe of his house, Pope Innocent IV., who forthwith laid him under the ban of excommunication, and, backed by the Guelphs and all the malcontents in the Two Sicilies, advanced to strip him of his power. Deserted by his subjects, and destitute of all means of raising troops, Manfredi was forced to free himself from the sentence of excommunication by agreeing to hold his possessions as an immediate fief of the Holy See. But the pope was unable to rest as long as Manfredi retained any power. Accordingly he began to organize a conspiracy against the liberty and safety of his vassal, which was only frustrated by the latter fleeing from the papal court and repairing for assistance to the Saracens of Lucera, the ever-faithful supporters of his house. With these rallying around him, Manfredi speedily recovered Apulia, and, aided by the death of Pope Innocent IV. in 1254, he received in 1257 the submission of the entire kingdom. In the same year the new pope, Alexander IV., inheriting the hostile spirit of his predecessor, presented the kingdom of the Two Sicilies to Edmund, second son of Henry III. of England, a gift, however, which that prince had not the courage to accept. A report that his nephew Conrad had died in Germany, induced Manfredi in 1258 to assume the title and insignia of king. No sooner had he taken this bold step, than envoys arrived from Conrad's mother to contradict the report, and to demand the resignation of the crown in favour of her son. But Manfredi refused to lay down the sceptre; and so much had his brave defence of his country, his handsome person, and his many accomplishments, endeared him to the hearts of his people, that Conrad's mother was fain to content herself with the promise that her son should be the next occupant of the throne. The elevation of Manfredi only stimulated the enduring enmity of Rome. On the accession of Pope Urban IV. in 1261, he was excommunicated, and his kingdom was placed at the disposal of any European prince who might have the strength to make it his own. At last Charles, Count of Anjou, and brother to Louis IX. of France, accepted the offer; but no sooner had he concluded the bargain with the Roman See than Urban died in 1264. Pope Clement IV. assumed the policy of his predecessor, and after crowning the Count of Anjou with great solemnity, sent him forth in January 1266 against the kingdom of the Two Sicilies. Manfredi, in the February following, encountered the enemy at Benevento. The Apulians passing over to the invaders at a critical moment in the fight, threw the entire Sicilian army into disorder. Manfredi, on seeing the desperate nature of his cause, spurred into the thickest of the battle, and fell covered with wounds. His mangled body was buried under a heap of stones; but ecclesiastical enmity, denying it even this poor resting-place, ordered it to be dragged out and conveyed to a barren valley on the confines of Abruzzo. There, in accordance with the sentence of excommunication, it was interred without any burial rites. Manfredi was the founder of the town of Manfredonia.

MANFREDI, *Eustachio*, an eminent mathematician and astronomer, was born in 1674 at Bologna in Italy. At first he studied philosophy and jurisprudence, and evinced a strong love for poetry, but latterly he devoted most of his time to mathematics and astronomy. He was appointed mathematical professor in the university of his native city in 1698, and surveyor-general of the rivers and waters in 1704. He was chosen regent of Montalto College during the same year, an office which he resigned in 1711 for that of astronomer to the newly established Institute of Bologna. Manfredi was chosen a foreign member of the Academy of Sciences at Paris, and of the Royal Society of London. He died of the stone in 1739. The principal of Manfredi's works are,—*Ephemerides Motuum Cœlestium ab anno* 1715 *ad annum* 1750, in 4 vols. 4to; *De Transitu Mercurii per solem anno* 1723, 4to, Bologna, 1724; and *De annuis Inerrantium Stellarum Aberrationibus*, 4to, Bologna, 1729.

MANFREDONIA, a seaport-town of Naples, province of Capitanata, stands at the head of a gulf of the same name, 19 miles S.W. of the promontory of Gargano, and 20 N.E. of Foggia; N. Lat. 41. 58., E. Long. 15. 56. This town is remarkable for its regularity and symmetry, and although many of the houses are unfinished, and some in a ruinous condition, it has an air of grandeur and uniformity seldom to be met with. The main thoroughfare is a long and wide street, extending from one gate to another; for the city is walled on all sides. Besides two gates to the land side, there are two others leading to the harbour, which is very safe, being protected towards the N. by a small breakwater; but on account of the little depth of water, it is accessible only to the smallest vessels. The town is also defended by round bastions, and by a strong castle, with a ditch and drawbridge, which commands the harbour. The inhabitants are cleanly and industrious, unlike the general character of the Italians, but their numbers have been much reduced by reason of the malaria arising from the neighbouring marshes. Since the recent draining of these marshes, however, the town has become more healthy. A considerable trade is carried on in salt, corn, and fruits, especially oranges. At the distance of a mile to the S.W. stood the ancient *Sipontum*, which was a Roman colony, and of which the only remains are two ancient pillars and a Saracenic church, which is still the cathedral of the archbishop. The modern town was founded by King Manfredi in 1266, and, though called by him *Novum Sipontum*, it afterwards took the name of its founder, which it still bears. Pop. 5000.

MANGALORE, a seaport-town and fortress of Hindustan, on the eastern shore of the Indian Ocean, in the province of Canara. It is large and well built, and is situated on a salt-water lake, which is separated from the sea by a beach of sand, but which communicates with a river. At high water, and in fine weather, ships drawing less than 10 feet can enter it; and there is good anchorage off the mouth of the river in from 5 to 7 fathoms water. The inhabitants are chiefly Mapillas or Moplas (Mohammedans), said to be descended from a colony of Arabians who settled in this place at a remote date. According to some traditions, the first mosque in the country was founded as early as 642, being only a short period after the commencement of the Mohammedan era. More sober authorities, however, refer this event to a period about two centuries later. Fanatical outbreaks on the part of the Moplas have unhappily not been uncommon of late years. Mangalore, though an indifferent haven, was the principal seaport of the territory of Hyder Ali and of his son Tippoo; and here were constructed the ships forming the maritime force of their realm, the teak forests on the slopes of the Ghauts affording abundance of the best timber. The exports consist principally of rice, which is sent to Muscat in Arabia, to Goa, Bombay, and Malabar. The other articles of export are,—betel-nut, black pepper, sandal-wood, cassia, and turmeric; in exchange for which, sugar, salt, and cotton piece-goods are imported. Mangalore was at an early period a great mart of trade, and was resorted to for this purpose by the Arabians. Here the Portuguese had also a factory, which was destroyed by the Arabians. In 1763 the town was taken by Hyder Ali, then the Mysore general; in 1768 it was captured by a detachment from Bombay, but was shortly afterwards retaken by Hyder. In 1783 Mangalore again surrendered to a force from Bombay; and after the destruction of General Matthews' army, sustained a long siege from Tippoo, and was gallantly defended by Colonel Campbell. Upon the conclusion of the peace in 1784, it was restored, and the fortifications were dismantled. In 1799, on the overthrow of Tippoo, it was finally taken possession of by the British. The population, exclusive of the military, has been returned at 11,548 persons. An excellent road from this town to Mercara, a distance of 80 miles, was constructed a few years since, at a cost of L.25,000. Distance from Bombay 440 miles; Seringapatam, 130. E. Long. 74. 54., N. Lat. 12. 52.

MANICA, a small state of Eastern Africa, in the territory of Monomotapa. It is generally mountainous, but is in many parts fertile, and affords pasturage to large herds of cattle. A considerable trade is carried on with the Portuguese, who exchange silk, linen, and iron, for gold, ivory, and copper, which are the chief articles of native produce. The capital of the same name is about eight days' journey W.N.W. from Sofala, in S. Lat. 18. 45., E. Long. 32. 50. Here the Portuguese have a fort with a small garrison of soldiers.

MANICHEISM, a scheme of religious eclecticism, which sprung up in Persia during the third century A.D., and rapidly spread through Syria and Palestine, Egypt and North Africa, as far as Italy, Gaul, and Spain. To its ensnaring philosophy Augustine fell an early victim, but lived to repent his error and to become its most vigorous assailant. The founder of the system was a Persian of the name of Mani, or Manes, a word derived by some from the Hebrew *Menahem*, which signifies the comforter or paraclete, but now generally regarded as from a Sanscrit root signifying a jewel or treasure. The eastern accounts of his history differ widely from the representations given by the writers of the western church, who wrote, however, under the bias of ecclesiastical dislike. From the oriental tradition we learn that he sprang from the sacred race of the Magi, that his family was among the most distinguished in Persia, and that in pomp of dress he always preserved the dignity of his house. He was a proficient in the mathematical sciences, had studied geography, and was an adept in the mysteries of music and painting. All these accomplishments he laid at the feet of the Christian church, and became a presbyter in one of the provinces bordering on Babylonia. His love, however, for the Parseeism of his country soon polluted his Christian teaching, and he was at once excommunicated and exiled for his faith. This latter calamity he owed to the rigour of Sapor I., to whom he unfolded his new gospel of a universal religion, but who was as little inclined to tolerate an inroad on Magianism as the Persian presbyters were to allow the corruption of their Christianity. Mani fled to the east, visiting India and even China, where he studied the principles of Buddhism in order to give a wider basis to his scheme. Returning to a grotto in Turkestan, while his followers believed he had ascended to heaven, he blended together the elements of his religious experience into a gorgeous picture-book, called afterwards the *Ertenki-Mani*, which became the sacred writing of the sect. On the death of Sapor he returned to Persia, when Hormisdas became his patron, and gave him a splendid residence in Susiana. Here he continued to spread his doctrines far and wide; but when Varanes succeeded to the throne, the jealousy of the Magians wrought his ruin. Mani was challenged to a conference, declared to be defeated, and flayed alive as a religious impostor. His skin, stuffed with straw, was suspended over the gate of the city of Sapor as a warning to all his adherents.

In the western accounts there is less both of consistency and romance. According to them, Manicheism owes its origin to a Saracen tradesman named Scythianus, who settled at Alexandria soon after the apostolic age, and bequeathed his doctrines to a pupil called Terebinthus. Soon after the death of his master, Terebinthus went to Babylon, where he assumed the name of Buddas, and pretended to have been born of a virgin, and to have been brought up on a solitary mountain by an angel. An unlucky fall from the roof of his house, however, cut short his days, and a young slave, called Cubricus, decamping with his manuscripts, and with them inheriting his wisdom, earned a more lasting reputation under the assumed name of Manes. At the court of Persia this impostor of the third generation succeeded in forming a school of disciples, whom he instructed and despatched abroad to disseminate his views. Having been unsuccessful in his treatment of one of the princes during a fatal illness, Manes was thrown into prison, and his apostles speedily returned to him with the intelligence that the Christians everywhere counterworked their charms. In the solitude of his dungeon he is said to have studied the Christian Scriptures; and, as soon as he was liberated, he proclaimed himself the promised Paraclete, commissioned to divulge and teach what Christ himself had left unspoken. With this new gospel Manes regained his former favour at the court; and from the Arabion, a castle on the borders of Mesopotamia, he was permitted freely to promulgate his views. A defeat which he suffered in open dispute with the Bishop Archelaus at Cascar, was the signal for his destruction (A.D. 277). Both accounts agree in the mode and circumstances of his death.

Tragic as was the fate of the founder of Manicheism, neither denunciation of divines nor tyranny of kings could daunt the adherents of this intoxicating heresy. In vain they were proscribed and trampled down. From Diocletian to Valentinian III. the severest statutes were framed against them. They were banished from their homes, and extruded from the common privileges of humanity; but after every wave of persecution, they reappeared to defend their doctrines, and the controversy was prolonged far into the middle ages. They are mentioned with as bitter hatred in the Koran as in the pages of Augustine.

It is impossible to give a full account of the Manichean system without expounding the systems from which it borrowed its constituent parts. These are given under separate heads in this work, and it is therefore only necessary here to note the particular dogmas of different creeds which were embraced within its vast eclecticism. These are admirably summed up by Dean Milman:—"From his native Persia he derived his Dualism, his antagonist worlds of light and darkness; and from Magianism, likewise, his contempt of outward temple and splendid ceremonial. From Gnosticism, or rather from universal orientalism, he drew the inseparable admixture of moral and physical notions, the eternal hostility between mind and matter, the rejection of Judaism, and the identification of the God of the Old Testament with the evil spirit, the distinction between Jesus and the Christ, with the Docetism or unreal death of the incorporeal Christ. From Cabalism, through Gnosticism, came the primal man, the Adam Cædmon of that system, and (if that be a genuine part of this system) the assumption of beautiful human forms, those of graceful boys and attractive virgins, by the powers of light and their union with the male and female spirits of darkness. From India he took the emanation theory (all light was a part of deity, and in one sense the soul of the world), the metempsychosis, the triple division of human souls (the one the pure, which reascended at once, and was reunited to the primal light; the second the semi-pure, which, having passed through a purgatorial process, returned to earth to pass a second ordeal of life; the third of obstinate and irreclaimable evil). From India, perhaps, came his Homophorus, as the Greeks called it, his Atlas, who supported the earth upon his shoulders, and his Splenditenens, the circumambient air. From Chaldea he borrowed the power of astral influences; and he approximated to the solar worship of expiring Paganism. Christ the mediator, like the Mithra of his countrymen, dwelt in the sun. From his native country Mani derived the simple diet of fruits and herbs; from the Buddhism of India his respect for animal life, which was neither to be slain for food nor sacrifice; from all the anti-materialist sects or religions, the abhorrence of all sensual indulgences, even the bath as well as the banquet,—and the proscription, or at least the disparagement, of marriage. And the whole of these foreign and extraneous tenets his creative imagination blended with his own form of Christianity; for so completely are they mingled, that it is difficult to decide whether Christianity or Magianism formed the groundwork of the system." (*Hist. Lat. Christ.* ii. 322 ff.)

This cumbrous and complex system had the strange power of evoking a fanaticism as keen as any that the world has ever witnessed; and the fanatical zeal of the sect was stimulated by a severe asceticism and a rigid gradation of ranks. Although the Manichean worship was simple and seldom, their daily life was tinged, in even the most trivial acts, by the presence of superstition. The members of the church were divided into the *perfecti*, or sacerdotal class, and the *auditores*, or catechumens. The head of the priesthood was Mani and his successors in office; and under him twelve apostles, and seventy-two bishops, with presbyters, deacons, and evangelists, formed a descending series of dignitaries. From their founder they received neither temple nor ceremonial. Prayers to the sun, and hymns to the divine principle of light, constituted their vocal worship. They observed the Lord's day, baptized with oil, and celebrated the Eucharist in water mingled with raisins. They rejected animal food, and tolerated marriage only in the inferior orders. Christmas and Good Friday had to them no meaning, as they denied the reality both of Christ's birth and death; but they hallowed annually the day of Mani's martyrdom. The purity of their morals is conceded by Augustine, and probably the eastern Manichees long continued to retain their unblemished character; but in Italy, at least, they soon sank into hopeless degradation.

The best special authorities on the subject of the Manicheans are,—Is. de Beausobre, *Hist. Crit. de Manichée*, Amst. 1734 and 1739; Matter's *Hist. du Gnosticisme;* and F. Chr. Baur's *Manichaische Religions-System*, Tüb. 1831; with Schneckenburger's Review in the *Studien und Kritiken*, iii., 1833.

MANILIUS, Marcus or Caius, a Latin poet, the author of *Astronomica*, an astrological treatise in five books. Regarding the facts of his life, and even his true name, great uncertainty prevails. In different MSS. he is called Manlius and Mallius, and other names slightly varying from each other. Different critics severally suppose him to be the senator Manilius; Manilius called the founder of astrology; and Manilius the mathematician; to all of whom allusion is made by Pliny in his *Natural History*. Yet all these suppositions rest on no surer grounds than the identity of the names, and the fact that all the persons mentioned must have been in a greater or less degree acquainted with astrology. From the internal evidence of his poem, it has been argued that Manilius flourished in the age of Tiberius, although Bentley places him in the Augustan age. The same great critic supposes him to have been a native of Asia, a conjecture that is by no means refuted by the circumstance, that Manilius talks in his poem as if he were a Roman citizen, and were living at the period at which he writes in the Roman capital.

The want of finish, and the abrupt conclusion of the *Astronomica*, evidently indicate that it was left incomplete. As a philosopher, Manilius has shown great talent in using all the astronomical lore of his day in selecting the most sagacious of conflicting opinions, and in starting some conjectures which have been fully verified in modern times. Yet, as a poet, his imperfect taste, and his pointless and inharmonious diction, fall far short of that genius which alone can elevate a scientific subject into the sphere of true poetry. The *Astronomica* was first discovered in manuscript by Poggio in 1416. From this copy the *editio princeps* was printed by Regiomontanus, 4to, Nuremberg, probably about 1472 or 1473. The standard edition is that of Bentley, 4to, London, 1739. A translation into English verse, by Thomas Creech, was published, 8vo, London, 1697, 1700.

MANILLA, capital of the island of Luzon, and of the group of the Philippines, is situated on the E. shore of the bay of the same name, on the S. bank, and near the mouth of the River Pasig; N. Lat. 14. 36., E. Long. 120. 53. The city proper is fortified, being surrounded by walls and a ditch, but it is not sufficiently strong to be able to stand a siege. The walls are about 2 miles in circuit, and the ditch is supplied with water from the River Pasig. The streets are regularly laid out and well paved, the carriage-ways being formed of quartz mixed with loam. The river is crossed by a bridge of ten arches, which leads to the suburb of Binondoc, in which most of the trade is carried on. Although in the town itself the houses are generally built of stone, in the suburbs bamboo is almost solely employed for building purposes. The houses have in general balconies; and the place of glass is supplied by thin plates of shell, which, though not transparent, are very effectual as a defence against the heat. In the suburb of Binondoc the houses are generally raised on wooden posts to the height of 8 or 10 feet, and the suburb in general presents more of an oriental appearance than the town, which is entirely Spanish in character. Binondoc is not so regular and well paved, but it affords a more agreeable variety of appearance. It is intersected by numerous canals, on which boats are continually plying. In the centre of the Spanish city there is a public square about 100 yards in length and breadth, surrounded on three sides by the governor's palace, the cathedral, and the government offices. The square also contains a bronze statue of Charles IV. of Spain, which was presented to the town by Ferdinand VII. in 1824. The town possesses many churches and convents, and a fine custom-house or Aduana. It has also a university, royal college, nautical academy, commercial school, an hospital, and a number of other benevolent institutions. Most of the buildings are of a substantial nature, being composed for the most part of volcanic tufa. Manilla, as seen from the bay, presents a grand and beautiful appearance; it is surrounded by hills, covered with verdure, which slope gradually down to the sea. On the land side of the town there is a large plain, which is set apart for military exercises, and round which there is a fashionable drive called the Calzada. The Pasig is navigable to some distance above the town for vessels of 200 or 300 tons burden; but there is a bar at its mouth with a depth of only 13 feet at low water. The trade of Manilla is considerable; but it is repressed by the restrictions imposed by the Spanish government. The principal articles of export are,—sugar, hemp, rice, indigo, various kinds of woods, tobacco, cigars, coffee, cotton, tortoise-shell, ebony, &c. The tobacco of the Philippines is of first-rate quality; but being a monopoly in the hands of government, its production is very limited. In the royal tobacco factory at Binondoc about 5000 women and 600 men are employed. The imports consist of iron, cotton and woollen stuffs, muslins, handkerchiefs, &c. The trade is principally in the hands of British merchants. The number of the clergy in the town of Manilla is very great; they are said to exceed in number the garrison, which consists of 7000. The religion is Roman Catholic. Manilla, which was formerly a native town, was first settled by the Spanish in 1571. It has been several times injured by earthquakes, especially in 1645, 1762, and 1824. In 1762 Manilla was taken by the

British, but was restored in 1764 to Spain for a ransom of L.1,000,000. Until the year 1809 no foreigners were allowed to trade here; but at that time an English house was allowed to be established, and in 1814 the same liberty was granted to all other nations. It is still, however, the only port in the Philippines at which vessels from Spain or the rest of Europe are permitted to trade. The population of the city itself is from 10,000 to 12,000, but, including the suburbs, the whole number of inhabitants is about 150,000.

MANISA, Manissa, or Manika, a town of Asia Minor, Anatolia, situated on the N. side of Mount Sipylus, 28 miles N.E. of Smyrna. This town was anciently called *Magnesia ad Sipylium*, to distinguish it from another town of the same name on the Mæander. It is chiefly celebrated in ancient history for the victory gained there by the Romans over Antiochus, in the year 190 B.C., after which it fell into the hands of the former. In the reign of Tiberius, it was much injured by an earthquake, but was restored by a grant of money from the emperor. The town is situated on the banks of the Hermus, and is noted as being one of the neatest and cleanest cities in Asia Minor. It contains about thirty mosques, two of which are adorned on the exterior with double minarets, and in the inside with paintings and other articles. The Armenians, Greeks, and Jews, have also their respective places of worship. There is also a fine khan, and a citadel which stands on a lofty rock, and commands an extensive view. The mountains near the town are remarkable for their loadstones, and hence the name "magnet" is supposed to be derived. The surrounding country is rich and productive, especially of saffron, which is exported. The town is the seat of some considerable trade, and many of the inhabitants are employed in the manufacture of cotton and silk goods, and goats' hair shawls. Pop. about 20,000.

MANLII, one of the most ancient and most illustrious of the patrician *gentes* of Rome. Its most notable members were the following:—

Cneius Manlius Vulso, who was curule ædile B.C. 197 (Liv. xxxiii. 25), prætor B.C. 195, and consul B.C. 189. Despatched in this last capacity to settle the affairs of Asia, he waged a successful war against the Galatians, and secured much booty. After remaining in Asia as proconsul during 188 B.C., and effecting the object for which he had been sent, Manlius Vulso set out with his army for Rome; but on his march through Thrace, he was attacked by the natives and stripped of a great part of his plunder. Not without some opposition was he honoured with a triumph in 186 B.C. (Liv. xxxvii. xxxviii. xxxix.)

Marcus Manlius Capitolinus, the deliverer of the Capitol, at an early age carried off the spoils of two enemies, was the first knight to win a mural crown, and gained six civic crowns and thirty-seven marks of distinction. (Pl. vii.) He was consul along with L. Valerius Potitus in 392 B.C.; and two years afterwards he saved the Capitol when on the eve of being captured by the Gauls. For this exploit, according to the ordinary opinion, he was honoured with the surname of Capitolinus. From this time Manlius seems to have fostered a morbid appetite for public applause. Accordingly, in 385 B.C., he placed himself at the head of the plebeians, then groaning under a burden of debts, and roused them to so great a fury against his own order, the patricians, that it was necessary to appoint a dictator. A. Cornelius Cossus, who was raised to this office, threw Manlius into prison, but owing to the clamours of the people, was soon afterwards obliged to release him. In 381 B.C. Manlius was arraigned before the people on the charge of aiming at sovereign power. According to the ordinary account, he overawed his judges during his trial by pointing to the Capitol in the distance, and not until the assembly had adjourned to a spot out of sight of that edifice was he convicted, and sentenced to be thrown from the Tarpeian rock. (Liv. vi. 11–20.) But another tradition represents him to have seized upon the Capitol (Dion. *Frag.* 31); and after holding it for some time, to have been captured and beheaded. (Gell. xvii. 21.) His house was razed to the ground, and the Manlian family decreed that none of its patrician members should take the name of Marcus. Gellius says, that in birth and valour Manlius Capitolinus was second to none, and in personal beauty, exploits, eloquence, and daring, superior to all (xvii. 2). (See Roman History.)

Titus Manlius Imperiosus Torquatus was the son of L. Manlius Imperiosus. When his father was on the eve of being prosecuted for cruelty towards his soldiers and his own son, Titus entered the house of his accuser, the tribune Pomponius, and pointing a dagger to his breast, threatened to strike him dead if he did not forthwith drop the prosecution. In consequence of this bold deed of affection he speedily became popular, and was soon afterwards elected a military tribune. But the greatest feat of Manlius was achieved when he was serving in the army that repelled the invasion of the Gauls in 361 B.C. In the sight of the two hosts on the banks of the Anio, he accepted the challenge of a gigantic Gaul, slew him, and spoiled him of his armour. From a golden chain (*torques*) which he took from the neck of his foe, he was henceforth surnamed Torquatus. (Liv. vii. 4, 5, 10.) After this Manlius was twice raised to the office of dictator, and thrice to that of consul. In his last consulship he conducted a war against the Latins; and while the two armies stood facing each other, he forbade any Roman, on pain of death, to engage one of the enemy in single combat. His own son disobeyed, and suffered the penalty by his father's order. Owing to this extreme severity, the triumph of Torquatus for his victory over the Latins was not attended by the young Romans. (Liv. viii. 3–12.)

Titus Manlius Torquatus was consul along with C. Atilius Bulbus in 235 B.C., when the temple of Janus was closed for the second time. (Liv. i. 19.) His second consulship was in 224 B.C., when, along with his colleague Q. Fulvius Flaccus, he waged a successful war with the Gauls, and was the first that led a Roman army across the Po. (Polyb. ii. 31.) In 216 B.C. he opposed the proposal to ransom the Romans captured at Cannæ. (Liv. xxii. 60.) Soon after this he defeated the Carthaginians in Sardinia, and reduced that island. He was offered the consulship in 210 B.C., but refused it on account of the weakness of his eyes. (Liv. xxvi. 22.)

MANNA, מָן; Sept. μαννά. The name given to the miraculous food upon which the Israelites were fed for forty years, during their wanderings in the desert, is first mentioned in Exod. xvi. It is there described as being first produced after the eighth encampment in the desert of Sin, as white like hoar-frost (or of the colour of *bdellium*, Numb. xi. 7), round, and of the bigness of coriander seed (*gad*). "When the children of Israel saw it, they said one to another, What is it? for they knew not what it was." (Exod. xvi. 15.) In the authorized and some other versions, this passage is inaccurately translated; which, indeed, is apparent from the two parts of the sentence contradicting each other. In the Septuagint the substance is almost always called *manna* instead of *man*. Josephus (*Antiq.* iii. 1, § 6), as quoted by Dr Harris, says,—"The Hebrews called this food *manna*, for the particle *man* in our language is the asking of a question, 'What is this?' (*man-hu*)." Though the manna of Scripture was so evidently miraculous, both in the mode and in the quantities in which it was produced, and though its properties were so different from anything with which we are acquainted, yet because its taste is in Exodus said to be like that of wafers made with honey, many writers have thought that they recognised the manna of Scripture in a sweetish exudation which is found on several plants in Arabia and Persia. The name *man*, or *manna*, is applied to this substance by the Arab writers, and was probably so applied even before their time. But the term is now almost entirely appropriated to the sweetish exudation of the ash trees of Sicily and Italy (*Ornus europæa* and *Fraxinus rotundifolia*). These, however, have no relation to the supposed manna of Scripture. Of this one kind is known to the Arabs by the name of *guzunjbeen*, being the produce of a plant called *guz*, and which is ascertained to be a species of tamarisk. The same species seems also to be called *toorfa*, and is common along different parts of the coast of Arabia, and in the neighbourhood of Mount Sinai. Burckhardt (*Travels in Arabia*, vol. ii., p. 51) says,—"It is from the *toorfa* that the manna is obtained. It is called by the Arabs *mann*. In the month of June it drops from the thorns of the tamarisk upon the fallen twigs, leaves, and thorns, which always cover the ground beneath the tree in the natural state. The Arabs use it as they do honey, to pour over their unleavened bread, or to dip their bread into; its taste is agreeable, somewhat aromatic, and as sweet as honey. If eaten in any quantity it is said to be highly purgative. Ehrenberg has examined and described this species of tamarisk, which he calls *T. mannifera*, but which is considered to be only a variety of *T. gallica*. The manna he considers to be produced by the puncture of an insect, which he calls *Coccus manniparus*. Others have been of the same opinion."

Another kind of manna, which has been supposed to be that of Scripture, is yielded by a thorny plant, very common from the north of India to Syria, and which by the Arabs is called *al-haj;* whence botanists have constructed the name Alhagi. The two species have been called *Alhagi maurorum* and *A. desertorum.* Both species are also by the Arabs called *ooshter-khar*, or "camel's thorn;" and in Mesopotamia, *agool*, according to some authorities; while by others this is thought to be the name of another plant. The *Alhagi maurorum* is remarkable for the exudation of a sweetish juice, which concretes into small granular masses, and which is usually distinguished by the name of Persian manna. Professor Don was so confident that this was the same substance as the manna of Scripture, that he proposed calling the plant itself *Manna hebraica.* These two, from the localities in which they are produced, have alone been thought to be the manna of Scripture. But besides these, there are several other kinds of manna. Burckhardt, during his journey through El-Ghor, in the valley of the Jordan, heard of the Beiruk honey. This is described as a substance obtained from the leaves and branches of a tree called *Gharb* or *Garrab*, of the size of an olive tree, and with leaves like those of the poplar. When fresh, this greyish-coloured exudation is sweet in taste, but in a few days it becomes sour. The Arabs eat it like honey. One kind, called *Sheer-khisht*, is said to be produced in the country of the Uzbecs. A Caubul merchant informed the author of this article that it was produced by a tree called *Gundeleh*, which grows in Candahar, and is about 12 feet high, with jointed stems. A fifth kind is produced on *Calotropis procera*, or the plant called *Ashur*. The sweet exudation is by Arab authors ranked with sugars, and called *Shukur-al-ashur*. It is described under this name by Avicenna, and in the Latin translation it is called *Zuccarum-al-husar*. A sixth kind, called *Bed-khisht*, is described in Persian works on *materia medica* as being produced on a species of willow in Persian Khorassan. Another kind would appear to be produced on a species of oak; for Niebuhr says,—"At Merdin in Mesopotamia, it appears like a kind of pollen on the leaves of the tree called *Ballot* and *Afs* (or, according to the Aleppo pronunciation, *As*), which I take to be of the oak family. All are agreed, that between Merdin and Diarbekir manna is obtained, and principally from those trees which yield gall-nuts." Besides these, there is a sweetish exudation found on the larch, which is called *Manna brigantiaca*, as there is also one kind found on the cedar of Lebanon. Indeed, a sweetish secretion is found on the leaves of many other plants, produced sometimes by the plant itself, at others by the punctures of insects. It has been supposed, also, that these sweetish exudations being evaporated during the heat of the day in still weather, may afterwards become deposited with the dew on the ground, and on the leaves of plants, and thus explain some of the phenomena which have been observed by travellers and others. But none of these mannas explain, nor can it be expected that they should explain, the miracle of Scripture, by which abundance is stated to have been produced for millions where hundreds cannot now be subsisted.

MANNERT, Conrad, a distinguished historian and geographer, was born at Altdorf in Bavaria, in 1756. After completing his studies at the venerable university of his native town, he was appointed professor in the principal educational institution of Nürnberg, a position which he exchanged in 1788 for that of rector of the gymnasium of St Gilles in the same city. In 1797 Mannert was elevated to the chair of philosophy in the university of Altdorf; and in 1808 he went to Landshut in the capacity of professor in ordinary of history, with the title of Aulic Counsellor; but this university being suppressed in 1826, he was appointed professor of geography and statistics at Munich, a situation which he held till his death in 1834.

As a historian Mannert is distinguished for accuracy and critical exactness. He verified his facts with the most scrupulous care, and he has become, in consequence, a weighty authority on geographical and historical subjects.

His *Geography of the Greeks and the Romans* is his most popular work, and is always referred to as a standard authority on that subject. His works are:—*Gesch. der Vandalen*, Leipz., 1785; *Gesch. der Nachfolger Alexanders*, Leipz., 1787; *Miscellanea*, Nürnberg, 1793; *Geographie der Griechen u. Römer*, Leipz., 1788–1825; *Compendium der deutschen Reichsgesch.* Leipz., 1803; *Statistik des deutschen Reichs*, Bamberg, 1806; *Die älteste Gesch., Bojoariens*, Nürnb., 1807; *Kaiser Ludwig IV.*, Landshut, 1812; *Handbuch der alten Geschichte*, Berlin, 1818; *Der Gesch. Baierns*, 1826.

MANNHEIM, or Manheim, the capital of the circle of Lower Rhine, in the grand duchy of Baden, is situated at the confluence of the Neckar and the Rhine, 34 miles N. of Carlsruhe, and 13 N.W. of Heidelberg. The town is built with great regularity and uniformity, and consists of eleven streets running in one direction, and crossed at right angles by ten others. The town is thus divided into squares of houses, which are distinguished not by names, but by numbers and letters of the alphabet. The houses are all two storeys in height, except those at the corners of the streets, which rise to the height of three storeys. The principal thoroughfares are lined with trees, and thus form agreeable promenades. The largest street, called Schrauken, is scarcely half a mile in length. The town was formerly fortified, but the defences were destroyed, and their site is now occupied by gardens and promenades. Both the Rhine and the Neckar are here crossed by bridges of boats, and the latter river has also a suspension bridge. In some of the public places there are fountains, which, however, are not supplied with water, as that is very scarce at Mannheim. The most remarkable building in the town is the magnificent palace of the grand duke, one of the largest in Germany, completed in 1729. It has a picture gallery, a gallery of copperplates, a collection of plaster casts from the most famous ancient sculptures, a collection of antiquities, and a museum of natural history, together with a library containing 60,000 or 70,000 volumes. Mannheim has several Roman Catholic and Lutheran churches, of which that of the Jesuits is the finest. There is a handsome observatory, with a tower 115 feet high, from which a fine view may be had; a theatre, merchants' hall, hospitals, &c. The principal educational institutions are a gymnasium, a botanic garden, and a mercantile school. There are also public baths, a club, and a reading-room. In the neighbourhood of Mannheim there are numerous gardens, and the park connected with the palace has an extent of 200 acres. There are at Mannheim manufactories of tobacco, shawls, linen, and cards; and bleaching and tanning are carried on to a considerable extent. The commerce of this town has been recently very much increased; the principle articles of trade are tobacco, corn, wine, wood, hops, linen, cattle, &c. Its position on two navigable rivers, and its connection by railway with most of the principal cities of Germany, are very favourable to its trade, and render it the first commercial city in the duchy. Till the year 1606 Mannheim was only a village, but at that time Frederick IV., the elector palatinate, enlarged and fortified it. During the Thirty Years' War it was taken by Tilly, Duke Bernhard of Weimar, the French, and the Bavarians. It was afterwards taken by the French in 1688; and in 1720 was made the seat of the electoral court. On the reigning family of Bavaria becoming extinct in 1777, the Elector Charles Theodore succeeded, and removed his court from Mannheim to Munich. It was taken by the French in 1795, by the Archduke Charles in 1799, was again occupied by the French, and finally in 1801, restored to Baden. Pop. (1852) 24,316.

MANNYNG, or MANNING, or DE BRUNNE, *Robert*, one of the English rhyming chroniclers who flourished at the end of the thirteenth and beginning of the fourteenth century, was born at Brunne, or Bourne, in Lincolnshire. He graduated at Cambridge, and lived as a Gilbertine canon, first at Semperingham, and afterwards at Sixhill, two priories in his native county. His first work was a free paraphrase into English rhyme of the *Manuel des Péchés* (Manual of Sins), a work of William de Wadington, in which the seven deadly sins are displayed in their most uninviting aspect by the aid of moral precepts and legendary tales. Another work of Mannyng was the *Medytaciuns of the Soper of our Lorde Jhesu, and also of his Passyun and eke of the Peynes of hys Swete Modyr Mayden Marye*, a metrical translation of Bonaventura's prose treatise *De Cœna et Passione Domini, et Pœnis S. Mariæ Virginis.* His chief translation, however, was his rhyming chronicle of England, in two parts. The former part, treating of that period of English history between the landing of the Trojans and the death of the Welsh Prince Cadwallader in 689, is translated from Wace's *Brut d'Angleterre*, and, like the original, is in the romance couplets of eight syllables. The latter part, which continues the history down to the death of Edward I., is taken from Peter de Langtoft's French Chronicle, and is translated into the Alexandrines of the original. This part has been published by Hearne under the title of *Peter Langtoft's Chronicle*, 2 vols. 8vo, Oxford, 1725. The first part is still in manuscript. Mannying gives indications in his works of untiring industry; but a facility in rhyming was the sole poetical faculty that he possessed. He is supposed by Hearne, but for no satisfactory reason, to be the author of the metrical romance of *Rycharde Cuer-de-Lyon.*

MANRESA, a town of Spain, capital of the partido of the same name in the province, and about 32 miles N.W. of the town of Barcelona. It lies on the left bank of the Cardonero, and about two miles above the junction of that river with the Llobregat. The Cardonero is crossed near the city by two bridges, one originally of Roman construction, and consisting of eight arches, the other of nine arches, erected in 1804. It is surrounded by walls, under which, on the bank of the Cardonero, is the only public promenade of the town. There are about 2300 houses of from three to five storeys, mostly well built, and the streets are causewayed and provided with covered sewers. The collegiate parish church, of semi-Gothic architecture, is capacious, and remarkable for a fine and lofty spire of bold construction, and for the fine sculpture and carving it contains. Also of good architecture is the ex-convent of Carmelites, which has some paintings of merit; that of the Dominicans has lost almost all trace of its primitive construction, and now serves as a barrack. There are several well-endowed and well-attended schools; an hospital under the care of the Sisters of Charity of St Vincent de Paul; and a female orphan asylum. The town is supplied with water from the Llobregat by an aqueduct 4 leagues in length, and by the wells, of which there are many within the walls. There are manufactories of cotton, cotton thread, silk ribands, earthenware, cutlery, leather, and superior brandy. The cotton factory is one of the largest in Spain. There are also saltpetre and gunpowder works. In the neighbourhood are quarries of building stone that might supply the whole kingdom, and coal has been discovered, but remains unworked. Manresa suffered much in the war of independence; in March 1811 it was almost completely burnt to the ground by Marshal Macdonald. The population in 1845 amounted to 13,339.

MANS, LE, a town in France, formerly capital of the province of Maine, and now of the department of Sarthe, is situated on the W. bank of the River Sarthe, 50 miles N.E. by N. of Angers, and 132 miles by railway S.W. of Paris. It is built on the slope of a hill near the confluence of the Sarthe and the Huisue, and consists of two parts, an old and a new town. The former is situated at the foot of the hill, and is irregularly built, with narrow, crooked, and for the most part dirty streets and lanes, but possessing many curious and interesting relics of ancient times, which are now fast disappearing. The new town is on a higher level, and is much better and more regularly built, having several fine streets and a spacious square called Place des Halles; but on the whole it is a dull and uninteresting place. There are also two good promenades,—Des Jacobins and Du Greffier, the latter of which extends along the banks of the Sarthe. Mans is chiefly remarkable for its ecclesiastical edifices, of which the principal is the cathedral of St Julien, comprising two styles of architecture, and dating from two if not more periods. The nave, which is believed to be of the twelfth century, is Romanesque, but it has pointed arches, while the side aisles and walls, and the west front, are at least as old as the eleventh century. The south doorway is richly carved, but much mutilated; while the choir is remarkably beautiful, and has very fine stained-glass windows. This church contains the tomb of Berengaria, queen of Richard I., and also the monument of Charles of Anjou, 1474, and of Langey du Bellay, distinguished as a warrior and author in the time of Francis I. and Henri II. The church of Notre Dame de la Coûture, has a very ancient choir, supposed to date from the tenth century, and of rude construction. The conventual buildings were formerly attached to the church, but these are now used for the prefecture, a museum of natural history and antiquities, and a library of 40,000 volumes. Besides these, there are also the churches of St Pierre and Notre Dame du Pré. The other chief buildings in Mans are the theatre, the theological and communal colleges, and the corn-market buildings. The manufactures of Mans consist of woollen stuffs, linen, lace, soap, paper, and leather. The commerce, which is considerable, is chiefly in these articles; and the products of the vicinity, such as iron, salt, wine, brandy, oil, corn, clover seed, cattle, pigs, poultry, &c. In the time of the Romans a town of the name of *Suindinum* stood here, and was the chief town in the district of the Cenimani. In the fourth century the town took the name of *Cenomania*, whence the present name. Its history, from the most remote period, is a series of disasters and devastations; and before the twelfth century it had been taken and pillaged twenty-six times. During the war of the League, Mans was besieged and obliged to surrender by Henri IV.; and in 1793 it was the scene of the destruction and final dispersion of the Vendéan army, when upwards of ten thousand persons were slaughtered. Pop. (1851) of the town, 24,568; of arrondissement, 173,102.

MANSAROWAR, or Mansahror, a lake situated on the northern side of the Himalaya Mountains, which divide Hindustan from Thibet and Tartary. It is considered by the Hindus as the most sacred of all the various places of pilgrimage, and they evince their zeal by the hardships and dangers which they endure in reaching it. It is also held in great veneration by the Tartars, who carry a portion of the ashes of their friends from a very great distance to be thrown into it. It is situated on an elevated plain covered with long grass; and to the N. is a conical hill dedicated to Mahadeva, and described as forming an irregular oval, approaching to a circle. It is 11 miles in breadth from N. to S., and 15 miles in length. It occupies the pilgrims five days to go round the lake, which from its form appears as if it had been the crater of a volcano. From this lake, according to the notions of the Hindus, flow four of their venerated rivers; but recent surveys have corrected this mistake, and it has now been satisfactorily ascertained that the only river which has its origin in this lake is the Sutlej. Moorcroft, who visited Lake Mansarowar in 1812, was of opinion that it had no considerable outlet. The water is clear and well tasted, and is supposed to be deepest in August and September, when it is replenished by the melting of the mountain snows. In the adjoining country are found wild horses, the yak of Tartary, and goats which produce shawl wool. It is supposed to be situated about 81. E. Long. and 31. N. Lat.

MANSART, François, a celebrated French architect, descended from a family originally Italian, was born at Paris in 1598. He was instructed in the principles of his art by his uncle, Germain Gautier, architect to the king, and first became known by his construction of several châteaus and hôtels. In 1632 he contributed the plan of the Eglise des Filles Sainte Marie. Not long afterwards Anne of Austria, the mother of Louis XIV., employed him to construct the Val de Grâce. After the structure had been partially erected, however, Mansart proposed to re-commence it on a new plan; but as this step met with the disapproval of the queen-mother, the completion of the edifice passed into other hands. The instability of purpose from which this slight arose became the besetting infirmity of Mansart, and afterwards prevented him from being intrusted with the buildings of the Louvre. Two of his masterpieces were the Eglise des Dames de Sainte Marie of Chaillot, and the Château de Maisons near St Germain-en-Laye. His last work was the façade of Eglise des Minimes in the Place Royale. He died at Paris in 1666. To him we owe the curb roof, which, after the name of its inventor, is still called a *mansard*.

Mansart, *Jules Hardouin*, a celebrated French architect, the son of Hardouin the painter, and of a sister of the above-mentioned François Mansart, was born at Paris in 1645. He studied architecture under his uncle, and afterwards assumed his name. Recommended to the notice of Louis XIV., he was intrusted by that monarch with the construction of many important edifices. His most notable works are the Château de Versailles and the Hôtel des Invalides. He also planned the Château de Marly, Château du Grand Trianon, the Place Vendôme, the Place des Victoires, the Château de Dampierre, and the church of Notre Dame at Versailles. As a reward for his services, Mansart received from Louis XIV. the Order of St Michael. He was also appointed chief architect and superintendent of buildings, arts, and manufactures. The large fortune which he reaped from these offices drew upon him much envy, and had he not been firmly fixed in the king's favour, it might have caused his downfall. He died suddenly in May 1708. Over his grave, in the church of St Paul at Paris, a tomb, executed by the sculptor Coysevox, was erected.

MANSFIELD, a market-town of England, county of Nottingham, pleasantly situated in Sherwood Forest, in a valley near the small River Maun or Mann, from which probably it takes its name, 14 miles N. by W. from Nottingham, and 147 from London by railway. The town is ancient, but contains also many good modern houses; and is paved and lighted with gas. In the market-place stands an elegant cross, recently erected in memory of Lord George Bentinck. The principal buildings in the town are,—the county hall, a theatre, and the parish church of St Peter, built principally in the Norman style, but repaired at different times in various styles. The other churches in the town belong to the Presbyterians, the Wesleyan and Calvinistic Methodists, and the Society of Friends. There is a grammar school, founded by Queen Elizabeth in 1567, and two charity schools, besides Sunday-schools attached to all the churches, and several benevolent institutions. The principal manufactures of Mansfield are cotton, hosiery, and lace. The trade of Mansfield, consisting chiefly of corn and malt, as well as in the building stone quarried in the neighbourhood, is much favoured by a railway connecting Mansfield with the Cromford Canal, and also by a branch of the North Midland Railway, which has its terminus here. Petty sessions are held here, and also the elections for the northern division of the county. The market-day is Thursday; and large cattle fairs are held three times a-year. Pop. (1851) 10,012.

MANSURAH, or El-Mansoorah, a town in Lower Egypt, and capital of a province of the same name, is situated on the right bank of the Damietta branch of the Nile, 34 miles S.W. of Damietta. It is one of the most considerable towns in the delta, and holds the sixth rank among the provincial towns in Egypt. The streets are narrow, and the houses are built chiefly of brick. It possesses a government cotton factory, a public school, and six mosques. There are no ancient ruins here or in the neighbourhood. Its principal manufactures are a sort of crape sail-cloth, and cotton and linen stuffs. (See Egypt.)

MANT, Richard, D.D., an eminent Irish prelate of the present century, was born at Southampton, where his father held a rectorship, on the 12th February 1776. He entered Winchester College in 1789, and Trinity College, Oxford, in 1793, where he took his bachelor's degree in 1797. He was elected a fellow of Oriel College during the following year, and he began his ecclesiastical career in 1804, as curate of Buriton in Hampshire. Mant was made vicar of Coggeshall in Essex in 1810, and of St Butolph's, Bishopsgate, London, in 1815, when he received the degree of D.D. from the university of Oxford. In 1820 he removed to Ireland, and was elevated to the bishopric of Killaloe and Kilfenora, where he remained till 1823, when he was translated to the see of Down and Connor. He died at Ballymoney in 1848, while actively pursuing the pious and philanthropic labours to which so much of his life had been devoted. Dr Mant is perhaps most generally known by his valuable *Commentary on the Bible*, which he edited in conjunction with Dr D'Oyley. Besides a vast number of sermons and tracts, and several poetical pieces, Bishop Mant is the author of *Biographical Notices of the Apostles*, &c., 1 vol. 8vo, London, 1828; *Scriptural Narratives of Christ's Life*, 1 vol. 8vo, Oxford, 1830; *History of the Church of Ireland from the Reformation to the Union of the Churches of England and Ireland in* 1801, 2 vols. 8vo, London, 1840.

MANTEGNA, Andrea, an eminent Florentine painter, was born of poor parents in the vicinity of Mantua, in 1431.

After a boyhood spent in tending flocks, he began the study of painting under Francesco Squarcione, a famous artist and teacher in Padua. So full of promise were his first attempts in the art, that his master received him into his own house, and adopted him as his son. At the age of seventeen Mantegna was intrusted in Padua with two important undertakings—the execution of an altar-piece for the church of Santa Sofia, and the painting of the chapel of San Christofano. While engaged in the latter work, he executed an altar-piece, which is now in the Brera at Milan. Mantegna sojourned for some time in Mantua, and there he secured the patronage of the Marquis Ludovico Gonzaga, for whom he painted some of his most beautiful pictures. One of these, "The Triumph of Cæsar," is considered his masterpiece, and is now seen at Hampton Court. His fame had now reached the hearing of Pope Innocent VIII., and accordingly he was summoned from Mantua to assist in the adornment of the newly-finished building of the Belvedere at Rome. Attended by the highest recommendations from his patron the marquis, he was kindly received by the pope; and after he had decorated in a most finished and elaborate style a small chapel in the palace, and had executed a picture of Our Lady with the Child, he was dismissed with much favour and honourable rewards. Mantegna was scarcely less eminent for engraving than for painting; and on his return to Mantua he executed on copper his famous picture of the Triumph. One of his last paintings was a representation of Michael the Archangel, St Andrew, St Maurice, and St Longinus, all kneeling before the Virgin with the Child, and commending to her care the Marquis Gonzaga and his wife. This picture was carried off in 1797 by the French, and is now in the Louvre at Paris. By his labours Mantegna had now earned a considerable fortune, and could thus sustain with due dignity the rank of knighthood, which had formerly been conferred upon him by his patron. He built for himself a handsome house in Mantua, where he died in 1517. Mantegna is celebrated by his contemporary Ariosto as one of the most illustrious painters of that age. "This master," says Vasari in his *Lives of the Painters*, "taught a much improved method of executing the foreshortening of figures from below upwards, which was without doubt a remarkable and difficult invention." He was esteemed for his upright conduct, and his gentle disposition, no less than for his great genius. (Lanzi, *Stor. Pittor.*)

MANTELL, Gideon Algernon, a distinguished geologist and palæontologist, was born at Lewes in Sussex in 1790. Having chosen the profession of a physician he commenced his career in his native town, where he soon established for himself an extensive practice, and began to cultivate the literature of his profession by contributions to medical journals. But it was as a man of science and as a lecturer that Mantell was destined to become known, and the accident of his position at Lewes, in the neighbourhood of an unwrought mine, by attracting his quick observation, and kindling his natural enthusiasm, directed his active energies towards that study which he afterwards enriched so greatly by discovery, and rendered so highly attractive by his happy talent for popular exposition. A richer field for observation and for the exercise of scientific tastes could scarcely have been found than that into which Dr Mantell was thrown, and few could have seized the opportunity with more zeal, or improved it with greater success. Previous to the time that he commenced his labours little was known of the nature of the Wealden formation, or of the fossils which it contained. Dr Mantell in a few years collected together from the Wealden and the chalk a museum of specimens of extinct reptiles, fishes, insects, and plants, which the trustees of the British Museum have since, at an expense of L.5000, made the property of the nation, and which alone would have been sufficient to have gained for the collector a permanent position among the promoters of geological science. The discovery and demonstration of four out of five of the strange genera of extinct Dinosaurian reptiles—viz., the *Iguanodon*, *Hylæosaurus*, *Pelorosaurus*, and *Regnosaurus*—are owing to Dr Mantell; and some of the most perfect existing remains of those singular creatures are to be found in the valuable collection of the Wealden geologist. Dr Mantell was elected a member of the Royal Society in 1825; and in recognition of his valuable labours in the comparative anatomy of fossils, and in his discovery of fossil reptiles, he was adjudged the Wollaston medal and prize by the Geological Society in 1835. During the same year he removed from Lewes to Brighton; and four years afterwards he came to London, and resided first at Clapham, and afterwards at Chester Square, still continuing his medical practice, and prosecuting with unflagging activity his favourite geological researches. In 1849 the council of the Royal Society presented Dr Mantell with the Royal Medal in acknowledgment of his discoveries in palæontology. He died at Chester Square, London, on the 10th of November 1852, aged sixty-two.

Dr Mantell did not take the position of a great generalizer or of the discoverer of new laws, yet his uncommon scientific ardour, combined with the accident of his position, and the requirements of the science, made him a great geologist. His success as a public teacher, as a popular expounder of geological facts, was unsurpassed during his time. By his numerous writings he has made a valuable addition to the geological literature of the British Islands. From 1813, when he published his first paper on the organic remains discovered in the environs of Lewes, to within a short period of his death, his literary labours were unceasing. In the *Bibliographia Zoologiæ et Geologiæ* of the Royal Society, the names of sixty-seven papers and works are given from Dr Mantell's pen. The most important of his works are,—"On the Iguanodon, a newly discovered fossil reptile, from the strata of Tilgate Forest, in Sussex," &c., *Phil. Trans.*, cxv.; "On the Discovery of the Hylæosaurus," &c., *Proc. Geol. Soc.* 1822; *Illustrations of the Geology of Sussex*, &c., London, 4to, 1827; *The Geology of the South-East of England*, 8vo, London, 1838; *The Wonders of Geology*, 2 vols. 8vo, London, 1838; *The Medals of Creation, or First Lessons in Geology*, 2 vols. 8vo, London, 1844. The last two works, besides meeting with a great degree of popularity in this country, have both been translated into German.

MANTES, a town of France, capital of a cognominal arrondissement in the department of Seine-et-Oise, is pleasantly situated on the left bank of the Seine, and connected with Limay, on the opposite bank, by two bridges and the island of Champion, which divides the river into two streams; 30 miles W.N.W. of Paris. The principal buildings are,—the church of Notre Dame, a Gothic edifice in the pointed style, with two towers and a roof of coloured tiles, which has been recently restored; the tower of St Maclou, also a Gothic structure, and the only remains of a church of the fourteenth century; the court-house; and the town-hall. It has flour-mills, tanneries, and breweries, and some trade in corn, wine, leather, &c. Mantes was taken, and reduced to ashes, by William the Conqueror, in 1087. Pop. (1851) of the town, 4298; of the arrondissement, 58,483.

MANTINEIA, a city of ancient Greece, in Arcadia, was situated on the River Ophis, near the confines of Argolis, in the centre of the valley now called the Plain of Tripolitza. It was built for the inhabitants of four or five separate villages, who had coalesced into one community, and is said to have taken its name from Mantineus, son of Lycaon. Its soldiers were engaged in the Trojan war (Hom. *Il.* ii. 607). As allies of the Spartans, the Mantineians sent their contingent to the battle of Thermopylæ. Jealous of the tyrannical policy of the Spartans, they joined the Athenian confederacy in the Peloponnesian war, but were defeated along with their allies at the first battle of Mantineia in 418 B.C. (Thucyd. v. 66–81). For some time after this they yielded a reluctant submission to the Spartans, until, on being commanded by the latter to raze their walls, they rose once more to assert their freedom. They were defeated, however, by Agesipolis, King of the Spartans, in 385 B.C., and were driven within their city. There, too, their invaders, by damming up the River Ophis on its exit from the city, and thus sapping the walls, forced them to submit. The Mantineians then retired to the humble villages in which their forefathers had dwelt, and not until the tyranny of Sparta had been broken at Leuctra (July 371 B.C.) did they return to the city, and, with the aid of the Eleians and Arcadians, rebuild the walls. (Xen. *Hell.* vi. 5.) About six years after the completion of this work, an alliance which the Mantineians had formed with their old masters the Spartans, turned against them the hostility of the Theban general Epaminondas. Accordingly, that great man encountered them in 362 B.C. at the second battle of Mantineia, and defeated them, though at the cost of his own life. In 295 B.C. a third action was fought at this city between Demetrius Poliorcetes and the Spartans (Plut. *Demetr.*); and in 242 B.C., a fourth, between the Achæans and the Spartans (Pausan. viii. 10). A league which the Mantineians formed with the Spartans in 228 B.C. once more brought them into disaster; and in 226 B.C., Aratus, leader of the Achæan confederacy, captured and occupied their city. The garrison, however, which he left was soon put to the sword, and the Mantineians continued to resist the Achæans until 222 B.C., when their city was taken and pillaged, and themselves were sold for slaves, by Antigonus Doson, King of Macedonia (Polyb. ii. 54, 58, 62). In honour of this monarch the city changed its name into Antigoneia, and it did not recover its former title until the time of Hadrian. In 207 B.C. the fifth battle of Mantineia was fought between the Lacedæmonians and Achæans. The ruins of Mantineia are seen around Paleopoli, and have been described by Leake in his *Travels in the Morea.*

MANTUA (Italian *Mantova*), a fortified town of Austrian Italy, capital of the delegation of the same name in the province of Lombardy, is situated on an island about 5 miles in circumference, standing in the middle of a lagune formed by the Mincio, and joined to the mainland by causeways perforated with arches; 21 miles S.S.W. of Verona, and 37 E. by N. of Cremona. Of the causeways the principal are the Ponte di Molini, leading to the Borgo di Fortrezza on the N., and the Ponte di San Giorgio, leading to the fortress and suburb of the same name. The latter is considered a masterpiece, and is 800 yards in length, crossing the entire lake. The city is very strongly fortified; for though the defences have not a very imposing appearance, both nature and art contribute to render it a place of very great strength. On the N. it is defended by the Borgo di Fortrezza and the Borgo di San Giorgio, the latter of which, along with the town, is surrounded by strong walls; to the S.E. it is defended by the outwork of Pradebba; and to the S. there lies the fortified island of Cerese, which is in the shape of a T, and is about twice the size of that on which the town is built. Many of the streets and squares in Mantua are broad and elegant, with well built houses; but for the most part the town is dirty and ill built. The Piazza Virgiliana is a fine square, planted with trees, and open on one side to the lake, and is much used as a public promenade. The other principal squares are,—the Piazza delle Erbe, where the market is held; the Piazza de San Pietro; and the Piazza del Argine. The principal public buildings are,—the cathedral, the work of Giulio Romano, and richly ornamented; the church of Sta. Andrea, considered one of the finest existing specimens of the Italian style, and adorned with statues of Faith and Hope by Canova; the ducal palace, an imposing building, remarkable for a fine floor of porcelain, and a room painted in fresco by Giulio Romano; the Palazzo del Te, which, though originally intended for the stables of the Gonzaga family, was increased by Giulio Romano to a large palace, and adorned by him with frescoes; and the house of Giulio Romano. There are also in Mantua numerous convents, a synagogue, an hospital, two orphan asylums, and other charitable institutions; a museum, a public library, containing 80,000 vols., as well as an arsenal, barracks, prison, &c. Mantua was formerly a place of some importance as a manufacturing town, and though now greatly decayed, still carries on some manufactures, the chief of which are,—leather, parchment, silk, linen and woollen stuffs, carriages, and boats. The climate of Mantua is subject to great extremes of heat and cold, and is rendered very unhealthy by the exhalations from the marshes with which it is surrounded. Recently, however, the Austrian government has taken measures to obviate this by draining the swamps and opening passages for the escape of the stagnant water. The city of Mantua is believed to be as old, if not older than Rome. It was not, however, distinguished until the time of Virgil. That poet was born at Andes, in the neighbourhood, which is reported to be the same as the modern Pietola. After the fall of the Roman empire, Mantua was possessed in turn by the Goths, the Longobards, and the Franks. After the conquest of North Italy by Charlemagne, Mantua became an independent republic; but afterwards became subject to the Marquises of Gonzaga, the last of whom was, in 1530, created, by the Emperor Charles V., Duke of Mantua. In the war of the succession Mantua was annexed to the Austrian dominions, of which it remained a part till the French, under Bonaparte, having gained possession of it in 1797, it became a part, first of the Cisalpine Republic, and then of the kingdom of Italy. It was finally restored to the Austrians in 1814. The delegation of Mantua is bounded on the N. by Brescia and the Lake of Garda, on the E. by Verona and Rovigo, on the S. by the duchies of Parma and Modena, and on the W. by Brescia and Cremona. Length about 36 miles, breadth about 32; area 903 square miles. The country is very fertile, and is watered by the Po, the Mincio, and the Oglio, besides many smaller streams and canals. The chief productions are,—wheat, silk, flax, hemp, fruits, wines, &c.; and horses and cattle are reared in great numbers. Pop. of the delegation (1850) 270,100, of the town (1851) 29,909, comprising 2500 Jews.

MANUEL, Jacques Antoine, a famous member of the French Chamber after the Restoration, was born at Barcelonette, in the department of Basses-Alpes, in 1775. After receiving his education at Nimes, he entered the battalions of the Requisition in 1793, and for his bravery was soon promoted to the rank of captain. On the signing of the treaty of Campo-Formio in 1797, he devoted himself to the study of law, and practised at the bar, first at Digne, and afterwards at Aix. Elected in 1815 to represent his native department in the Chamber of Deputies summoned by Napoleon, he gained his first notoriety by vehemently opposing the restoration of the Bourbons. His patriotic eloquence, though unsuccessful in attaining its object, was probably the cause of his return to the Chamber in 1818. Manuel then became an ardent defender of the benefits that France had reaped from the revolution. Borne forward by his power of logic and his heroic firmness into the front ranks of the Opposition, he soon incurred the dislike of the ruling majority, and was destined to become an object of their vengeance. During the violent debates on the Spanish war in 1823, a remark in one of his speeches was construed by his enemies into an apology for regicide. His expulsion from the Chamber was decreed, and he was forced out by a body of soldiers, but was accompanied to his house by the whole of his party. Manuel was re-elected in 1824, and died in 1827.

Manuel I., *Comnenus*, Emperor of Constantinople, son of John II., was born about 1120. The warlike disposition which he showed in an expedition against the Turks induced his father, at his death in 1143, to bequeath to him the crown in preference to his elder brother Isaac. Through the zealous policy of his faithful minister Axuch, and his own popularity among the soldiers, Manuel was enabled to secure his father's gift. Fond of military glory, he immediately involved himself in that long series of wars which continued, with few intermissions, till the end of his reign. In 1144, by means of his general Demetrius Branas, he subdued his rebellious vassal Raymond, Prince of Antioch. The next year was rendered illustrious by his expedition into Isauria, during which he routed the invading Turks, drove them to their own dominions, and forced them to accept a truce on his own terms. Manuel, however, employed a cowardly policy towards Louis VII. of France and Conrad III. of Germany, the leaders of the crusade of 1147. Granting them a passage through his dominions, he yet secretly harassed them with every kind of annoyance, and apprised the Turks of their approach. Meanwhile Roger, the first King of Sicily, had declared war against the Emperor of the East, had taken Corfu, and had devastated Greece. Manuel, however, did not make reprisals until the Sicilian fleet, in 1148, had appeared before Constantinople, and had insulted the imperial city. He then formed a league with Venice, and joining his own well-equipped fleet with that of the republic, he swept the invaders from the Archipelago and the Ionian Sea, and captured seventeen of their galleys. Disembarking a host at Corfu before the year had ended, he invested that city both by sea and land; and by leading in person the most perilous onsets, and encouraging his men by his own prodigies of strength and valour, he compelled the inhabitants to surrender after an obstinate siege. In the prosecution of the same war Manuel subdued the Servians and Hungarians, who had risen in arms at the instigation of Roger. An expedition, which he had sent against Italy under Palæologus, was also successful. Bari, Brundusium, and many other towns of Apulia and Calabria, surrendered, and Manuel now formed the project of uniting the Eastern and Western Empires, and of constituting himself sole Emperor of the Romans. By the aid of money he induced Pope Alexander III., and the free cities of Lombardy, to favour this design. But the pontiff soon afterwards changed his opinions; the free cities followed his example, and the republic of Venice, offended at some injustice offered to her merchants, also joined the foes of the Greek Empire. The death of Palæologus, his lieutenant, and the accession of William the Bad to the throne of Sicily, soon completed the sum of Manuel's misfortunes. His forces soon afterwards were defeated by land and sea, and he was induced in 1155 to conclude an honourable peace with William, King of Sicily.

The next important war of Manuel's reign was waged against Geisa, King of Hungary. That prince, eager to recover the military reputation he had lost in his former battles with the Emperor of the East, crossed the Danube, and met the Greek forces, under Andronicus Contostephanus, near Zeugminum, where, after a stubborn and sanguinary contest, the Hungarian army was almost annihilated, and Geisa compelled to sue for immediate peace. Not so successful was the expedition which Manuel led in person against the Turks in 1176. He lost his army among the mountains of Pisidia, and was compelled by the Sultan Az-ed-diu to sign a disadvantageous peace. This defeat, although partially retrieved by a more successful expedition in 1177, preyed upon the spirit of Manuel until he was cut off by a slow fever in 1181. The bravest warrior of his time, Manuel was yet destitute of the prudence and the stability of purpose proper alike to a great general and an able ruler. No sooner had he brought a war to a close, than he dismissed all thought of military enterprise, and in the long-continued indulgence of every sensual pleasure entirely forgot his former ambition. The exorbitant war taxes, wrung from the reluctant grasp of his subjects, were often expended for some unworthy purpose, while his soldiers remained unpaid. Alexis II., his only son, succeeded him.

Manuel II., *Palæologus*, Emperor of Constantinople, succeeded his father John VI. in 1391, died in 1425, at the age of 77, and was succeeded by his son John VII. (See Constantinopolitan History.)

MANUFACTURES.

Definition. Manufactures (Latin, *manus*, a hand, and *facio*, I make), in political economy, a term employed to designate the changes or modifications made by art and industry in the form or substance of material articles, in the view of rendering them capable of satisfying some want or desire of man.

With the exception of fishing, hunting, mining, and such branches of industry as have for their object to obtain material products in the state in which they are fashioned by nature, all other branches may legitimately be comprised under the term *Manufactures*. Most commonly, indeed, we include in them only those branches in which the raw material or substance to be modified or worked upon is formed or converted into the desired articles by art and industry, without the intervention of the soil or of the vegetative powers of nature. But though this limitation of the term manufactures be in many respects convenient, it must not be supposed that by adopting it, we mean to insinuate that there is any real or substantial difference between the various divisions of industry. Agriculture is merely a peculiar variety of manufacture, in which the husbandman so prepares the ground and disposes of the seed, that, with the aid of the soil, and of the sun and showers, he may obtain a plentiful harvest. Without the assistance given by nature, his efforts would not be of the smallest avail. But her bounty is not confined to this or that department. It extends to, and is equally great in them all. Without the pressure of the atmosphere, the elasticity of steam, the influence of heat, and the endless variety of natural powers by which he is constantly assisted, the manufacturer would be powerless, and could not even make or mend a pen, or accomplish the most trivial task. His art consists in so applying his own labour and the natural powers at his command, that they may bring about the required changes or modifications in the articles subjected to their action in the best and cheapest manner. At bottom all the branches of operative industry rest on the same foundation. How much soever one undertaking may differ from another, the co-operation of genius and industry, of man and of natural agents, is necessary in them all. And hence, also, it follows, that they are all susceptible of indefinite improvement according as the progress of scientific discovery gives man a greater mastery over these agents, and enables him to employ them and his own energies with increased effect.

Elements which enter into the value of manufactured articles.

The value of manufactured articles may always be resolved into the value of the raw material or matter[1] on which the skill and labour of the artisan is exerted, and the value of that labour. These may, and, in fact, do vary in almost every degree as compared with each other. In some articles they approach near to equality; in others, as in most descriptions of gold and silver wares, the value of the raw material predominates very largely; and in others the value of the workmanship is by far the greatest. The value of the main-spring of a watch, or of a steel pen, is some hundred times that of the iron of which it is made; and the value of statuary, pictures, and other products of the fine arts, is almost wholly owing to the genius and labour of the artist.

In nothing, perhaps, is the transforming power of manufacturing industry—its ability to give to matter entirely new forms and new qualities—more strikingly evinced than in the production of glass and paper. It is impossible to exaggerate either the utility or the beauty of these fabrics. To the former we are mainly indebted for the comfort of our houses, and for that range and intensity of sight which enables us to survey regions at an almost inconceivable distance, and to detect and appreciate the minutest objects; while to the latter we owe the means by which our correspondence is carried on, our books, and, in fact, the greater part of our knowledge. And these inestimable *commoda vitæ* are formed out of such despised materials as sand, soda, and rags. In this case, and in that of many other articles, the metamorphosis is so very complete, that none who saw only the products, and knew nothing of their manufacture, would ever conjecture whence they had been derived. Though not productive of matter, industry is often productive of everything which makes it either desirable or valuable.

In saying that the value of manufactured goods is made up of the value of the raw material and the workmanship, it may perhaps be objected that nothing is set down to the account of natural agents. But though their co-operation be of the utmost importance, and generally, indeed, quite indispensable, yet as they are spontaneous gifts of nature, which may be appropriated by every body, and cost nothing, they have no exchangeable value, and cannot communicate a quality of which they are destitute to any thing else. In estimating, for example, the cost of importing a cargo of tea from China, or the value of the work performed by a locomotive engine, the buoyancy of the water, the action of the wind, the polarity of the magnet, and the expansive force of heated aqueous vapour, though contributing in the most essential manner to the results which, in fact, could not be accomplished without their powerful aid, are as completely left out of view as if they did not even exist. This principle is of fundamental importance, and holds universally. Whatever is useful or desirable in art and industry is a consequence or result of the labour or action of man, of capital, or of natural agents, or of two or all three combined. But in so far as the latter are concerned, their services are completely gratuitous; so that the cost or value of the result is always measured, without any reference to them, by the amount of labour or capital (the product of labour) or both, necessarily expended in bringing it about.

In this article manufactures are considered in their ordinary and limited sense, as comprising the processes whereby the required changes or modifications are produced, independently of vegetation, in existing substances or materials. The latter usually give their names to the peculiar departments wherein the processes to which they are severally subjected are carried on. Thus the designations of cotton, silk, and woollen manufactures, mean the working up of cotton-wool, raw silk, and sheep's wool into useful or desirable articles. Ship-building is the conversion of iron and wood, or of either, into ships. The linen manufacture is the conversion of flax into cloth; and so on. The knowledge of the modes in which particular businesses may be most profitably conducted, forms the peculiar science, craft, or mystery of those engaged in them.

It would far exceed our limits to enter into any details in regard to the management of different businesses; but there are certain circumstances or conditions which are necessary, and others which eminently contribute to the success of all varieties of manufacturing industry, and these we shall endeavour shortly to state. We shall also take leave to notice some of the peculiar drawbacks by which the great extension of manufactures is said to be accompanied, with the means by which they may be most effectually obviated, the economy and locality of factories, &c.

I. CIRCUMSTANCES FAVOURABLE TO THE PROGRESS OF MANUFACTURING INDUSTRY.

Circumstances conducing to the progress of manufactures.

These are partly of a moral and political, and partly of a physical description. Of the former class the most important seem to be the security and free disposal of persons and property; the absence of monopolies, and the non-interference of government in industrious undertakings; the freedom of commerce; the diffusion of knowledge; the cordial reception of foreigners; and the emulation and energy inspired by inequality of fortune and the gradual increase of taxation. Among the more prominent of the physical circumstances conducive to their progress are,—supplies of the raw material used in manufactures, with the command of power; that is, of coal, waterfalls, &c. A good deal also of the progress of manufactures seems to depend on the advantageous situation of a country for commerce, and on the nature of its climate. We shall briefly notice some of the more prominent of these circumstances.

Moral circumstances contributing to the progress of manufactures.

a. Moral circumstances contributing to the Progress of Manufactures.—It is unnecessary to take up the reader's time by enlarging on the necessity of security, and of the free disposal of property, to success in manufacturing industry, and, indeed, in all laborious undertakings. Without security there can be neither industry nor invention. No man will engage in any undertaking, or exert either his bodily or mental powers, unless he be well convinced that he will be allowed to reap whatever advantage may accrue from the exertion of his labour, skill, or genius. Any doubt as to this is sure to paralyze his efforts. And if, owing to the weakness or ignorance of government, the prevalence of a revolutionary spirit, or other cause, the security of property were materially impaired, all sorts of industrious undertakings that did not promise an immediate return would be forthwith abandoned, and every person possessed of property would hasten to convey it out of the country. The want of security is the greatest of public calamities. Without it we can have nothing but the most abject poverty and barbarism. And supposing other things to be equal, the wealth and civilization of nations will be pretty nearly proportioned to the degree of security they respectively enjoy. Though every other circumstance conducive to the advancement of industry should exist in a country, they cannot, without security, be of any

Security.

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[1] It is unnecessary for the purposes of this article to analyze the value of the raw material. In point of fact, however, it is wholly made up of the value of the labour required for its appropriation and conveyance to the place where it is to be modified or manufactured. The matter of commodities costs nothing. What is commonly called raw material has frequently a great deal of labour expended on its manufacture, as in the case of pig or bar iron, cotton wool, raw silk, flax, &c.

matcrial service. It compensates for many deficiencies; whereas nothing can make up for its wants. It is a *sine quâ non.*

By the security indispensable to success in manufactures is not, however, meant that degree of security which exists in most countries that have made any progress in civilization, viz., the free enjoyment of the fruits of one's labour or ingenuity. Much more than this is required to make industrious undertakings be prosecuted on a grand scale with zeal and perseverance. Administration must be established on such a basis that the freedom and independence of those by whom manufactures are carried on may be as effectually secured as their property. The latter must be guaranteed against all arbitrary proceedings, whether on the part of government or of private parties. The standard of money must be preserved inviolate; public burdens fairly and equally imposed; justice speedily, cheaply, and honestly administered; and testators have full liberty to dispose of their property as they may think fit. Wherever any of these things are wanting, there can be no complete security; and, therefore, none of that unhesitating confidence which makes capitalists invest large sums, of which posterity is to reap the principal or entire advantage; and which also gives its fullest extension to private and public enterprise and credit. That accumulation of capital which has taken place in England during the last hundred years, and which, besides enabling us to defray with little difficulty the cost of so many protracted and destructive wars, has covered the land with cities and all sorts of improvements, and the ocean with ships, would either not have taken place at all, or but in a very subordinate degree, had there been any serious doubt about its present or future security, or about the ability of the owner to employ it or bequeath it at pleasure. The various circumstances that will be immediately mentioned give us peculiar means and advantages for the production of wealth. But the consciousness of security is required to make these circumstances be turned to the best account, and the produce of industry largely saved and accumulated. And the more intense this consciousness becomes, the greater, *cæteris paribus*, will be the progress of the society in arts and industry.

Freedom of industry.

The absence of monopolies, and the freedom to engage in industrious undertakings, conduce in no ordinary degree to the advancement of the arts. Every man is always exerting himself to find out how he may best extend his command over necessaries and conveniences; and sound policy requires that so long as he does not interfere with the rights and privileges of others, he should be allowed to pursue his own interest in his own way. Though human reason is limited and fallible, and we are often swayed by prejudices, and deceived by appearances, still it is sufficiently certain that the desire to promote our own purposes contributes more than anything else to render us clear-sighted and sagacious. "*Nul sentiment dans l'homme*," says M. Say, "*ne tient son intelligence éveillée autant que l'intérêt personnel. Il donne de l'esprit aux plus simples.*" The principle that individuals are, speaking generally, the best judges of what is most beneficial for themselves, is now universally admitted to be the only one that can be safely relied on. No writer of authority has latterly ventured to maintain the doctrine, once so popular, that governments may advantageously interfere to regulate the pursuits of their subjects. It is their duty to preserve order; to prevent one from injuring another; to maintain, in short, the equal rights and privileges of all. But it is not possible for them to go one step further without receding from the principle of non-interference, and laying themselves open to the charge of acting partially by some and unjustly by others.

The most comprehensive experience confirms the truth of these remarks. The natural order of things has been less interfered with in Great Britain than in most other countries. Since the passing of the act of James I., in 1624, for the abolition of monopolies, full scope has been given to the competition of the home producers; and though the various resources of talent and genius have neither been so fully nor so early developed as they would have been had there been no restrictions on our intercourse with foreigners, they have been developed in a degree unknown to most other countries. France, previously to the Revolution, was divided into provinces, having each peculiar privileges and separate codes of revenue laws, and this also was the case with Germany, Spain, and Italy, so that they were not only deprived of the freedom of foreign, but even of internal, commerce. The inhabitants of each province being in great measure isolated from the rest, there was comparatively little competition; and instead of invention and active exertion, there was nothing but routine and indifference. Holland and the United States have been the only countries that have enjoyed the same degree of internal freedom as Great Britain: And the former, notwithstanding the unfavourable physical circumstances under which she is placed, has long been, and still is, the richest country of Europe; while the latter, whose condition is in other respects more favourable, is advancing with giant steps in the career of improvement.

But the freedom of the home trade, or the stimulus given to invention by the competition of the different parties within the same country, how advantageous soever, is always very inferior to the stimulus given by an unrestricted foreign trade. A nation which admits, either freely or under moderate duties, the various productions of others, adopts that line of policy which is sure to bring her energies into the fullest activity. She profits by whatever inventions and discoveries may be made in countries the most remote, as well as among her nearest neighbours; at the same time that her manufacturers have not only to contend with each other, but with those of every other people. In a system of this sort, no branch or department of industry can be artificially bolstered up. Each must depend upon its own resources. And if, during a restricted trade, a business were introduced into a country which had no peculiar aptitude for carrying it on, it would most likely be extinguished when trade was made free. But this extinction, instead of being a loss to such country, is a gain. The capital and labour which were engaged in an unprofitable business, will henceforth be diverted to those pursuits which the inhabitants can carry on with more advantage; and their wealth, and that of the community of nations, will be increased by the better distribution of their labour.

Division of employments.

It would be useless to enter, even if our limits permitted, into any lengthened details in regard to the advantages resulting to society from the division of labour; that is, from the execution of certain tasks or duties being committed to particular persons, possessing the age, strength, skill, and other qualifications required for their proper performance. These have been set in a clear light by Adam Smith and others, and are familiar to everybody. But it is not, perhaps, so generally known, that the division of labour is in a great degree dependent on the extent of the market, and that it becomes more perfect and complete according as the latter is more and more extended. There are many employments that cannot be carried on in thinly peopled countries; and of those that are, or may be, carried on in them or in others, there is hardly one which may not be improved and perfected by increasing the demand for the peculiar services or articles which it furnishes. To be satisfied of the truth of this statement we have only to look around us. Take the case of the cotton, the woollen, or the iron manufacture. These great departments of industry could not have attained to such vast magnitude, or been furnished with the complex machinery and the skilfully distributed labour employed in them, had the demand for their products been confined to a single province, or even to a single kingdom. Nothing less extensive than the market of the world would afford a field wide enough to keep them in constant employment. And hence it is, that while the freedom of trade stimulates the industry and ingenuity of the home producers, by bringing them into competition with myriads of foreigners, it affords an illimitable market for those products in which they have a superiority; and enables them continually to perfect every process, and to carry the employment of machinery and the division of labour to the greatest extent.

Extension of industry since 1842.

It is needless, however, to insist on considerations the justice of which is now all but universally admitted. But it was necessary, nevertheless, thus briefly to allude to them, inasmuch as they satisfactorily account for the greater part of the late extraordinary increase of our trade; that is, of its increase from the time that the commercial reforms of Sir Robert Peel came into full operation. Since 1842 the declared annual values of the exports of British produce have been as follows, viz.:—

Years.	Annual value.	Years.	Annual value.
1842	L.47,381,023	1850	L.71,359,184
1843	52,279,709	1851	74,488,722
1844	58,584,292	1852	78,076,854
1845	60,111,082	1853	98,933,781
1846	57,786,876	1854	97,184,726
1847	58,842,377	1855	95,688,085
1848	52,849,445	1856	115,890,857
1849	63,596,025		

The raw products included in the exports consist principally, as usually estimated, of unwrought iron, copper, tin, and lead; with coal, sheep's wool, butter, fish, salt, and a few other articles; their entire value not exceeding a seventh or an eighth part of the value of the exports. But we are by no means satisfied that iron and other metals should be reckoned in the list of raw products. On the contrary, we are clear that that designation should be restricted to the ores of the metals, and that it should not be applied to the metals after they have been extracted by an elaborate process from the ores. And supposing this classification were adopted, and the unwrought metals excluded from the list of raw products, the latter would not exceed a fifteenth or a sixteenth part of the entire amount of the exports.

The unprecedented increase in the value of the exports, exhibited in the above table, is in great measure the result of the policy of Sir Robert Peel, who, by repealing and greatly reducing the duties on most descriptions of foreign produce, occasioned a vast increase of importation. But he knew well that a great importation would occasion a great exportation; that the latter would increase in the same ratio as the former; and that by a free intercourse with others our manufacturing and industrial powers would be sharpened and improved to the utmost. And such has proved to be the case in a far greater degree than he, or any one, however sanguine or far-sighted, could have anticipated. The new system has brought all the faculties of the mind, and powers of the body, into full activity. And while the improvements of a century have been crowded into the short space of ten or a dozen years, we continue with unimpaired energy to make new inventions and discoveries.

But though the extraordinary increase of our trade since 1842 has been mainly (we should err if we supposed that it was wholly), owing to the greater freedom it has enjoyed during that period. Part of it is to be ascribed to the discovery of the gold-fields of California and Australia. Their astonishing productiveness, the encouragement they have given to emigration, and the rapid growth of a population which has had an almost unbounded command of the precious metals, at the same time that it has been destitute of most articles of accommodation, have led to an extraordinary demand for foreign produce, and especially for our manufactures. But it must not be forgotten that it was our comparatively free commercial policy that enabled us to avail ourselves to so great an extent of these advantages; and the presumption is, that but for it, we should have profited as little by them as the countries around us.

Diffusion of information.

The ability to read, and the diffusion of instruction among all ranks and orders of the people, by the circulation of books and journals, the establishment of mechanics' institutes, &c., have had a material influence over the advancement of arts and industry. These circumstances have had the double advantage of multiplying the means and chances of improvement, and of preventing any invention or discovery, when made, from being lost or engrossed by a few. An uninstructed people, though possessed of the greatest capacities for the production and accumulation of wealth, being unable to turn them to good account, are usually poor and destitute; whereas an intelligent people, though placed in a comparatively unfavourable situation, never fail to become rich and prosperous. That "knowledge is power," is true in a physical as well as in a moral sense. The more familiar our acquaintance with, and the more complete our command over, natural agents, the greater, of course, will be our ability to make them subservient to our purposes, and to employ their untiring and boundless energies in the performance of that labour that must otherwise be wholly performed by man. The proud pre-eminence of civilized man over his less advanced brethren, mainly consists in the extensive employment of these agents. Like other things, production is proportioned to the strength of the means by which it is effected. The accommodations of a people in a low or backward state of civilization, who have nothing but their fingers and a few rude tools or simple instruments at their disposal, are necessarily limited in the extreme; whereas a people highly advanced in the arts press all the powers of nature into their service, and have an all but unlimited command of the various articles required for their subsistence and wellbeing.

Immigration of foreigners.

For a lengthened period the reception given to foreigners in England was anything but cordial. In most countries, indeed, not advanced in civilization, strangers are uniformly the objects of popular dislike; and this feeling seems to have prevailed quite as much in England as anywhere else. But notwithstanding the various legal disabilities laid on foreigners, and the ill treatment they often experienced, their settlement here has been productive of the most advantageous results. The Flemings, invited over and protected by Edward III., gave the first great impulse to the woollen manufacture; and the immigrations from the Low Countries during the persecutions of the Duke of Alva, and from France subsequently to the revocation of the Edict of Nantes, materially forwarded our trade and manufactures. During last century the prejudice against aliens lost much of its force; and most part of the disabilities under which they formerly laboured have been removed. But in all that respects the treatment of foreigners our policy has been less liberal and enlightened than that of the Dutch. In Holland they have always been received with open arms; and a short residence in the country, and a small payment to the state, entitled them to all the privileges enjoyed by natives. The highest authorities agree that this was one of the main causes of the extraordinary progress made by the republic in commerce and wealth. "It has always been our constant policy to make Holland a perpetual, safe, and secure asylum for all persecuted and oppressed strangers: no alliance, no treaty, no regard for, nor any solicitation of, any potentate whatever, has at any time been able to weaken or destroy, or make the state recede from protecting those who have fled to it for their own security and self-preservation. Throughout the whole course of all the persecutions and oppressions that have occurred in other countries, the steady adherence of the republic to this fundamental law has been the cause that many people have not only fled hither for refuge, with their whole stock in ready cash, and their most valuable effects, but have also settled and established many trades, fabrics, manufactures, arts, and sciences, in this country; notwithstanding the first materials for the said fabrics and manufactures were almost wholly wanting in it, and not to be procured but at a great expense from foreign parts."[1]

Inequality of fortune.

The great inequality of fortune that has always prevailed in this country has had a material influence in exciting a spirit of invention and industry among the less opulent classes. It is not always because a man is absolutely poor that he is industrious and economical. He may have already amassed considerable wealth; but he continues with unabated energy to avail himself of every means by which he may hope to add to his fortune, that he may place himself on a level with the great landed proprietors, and those who give the tone to society in all that regards expense. No successful manufacturer or merchant ever considers that he has enough till he is able to live in something like the same style as the most opulent noblemen. Those, again, who are immediately below the highest become a standard to which the class next to them endeavour to elevate themselves; the impulse extending in this way from one rank to another, till it reaches to the very lowest classes, individuals belonging to which are always raising themselves by industry, address, and good fortune to the highest places in society. Had there been less inequality of fortune amongst us, there would have been less emulation, and industry would not have been so earnestly prosecuted. It is true, that the desire to emulate the great and the affluent, by embarking in a lavish course of expenditure, is often prematurely indulged in and carried to a culpable excess. But the evils thence arising make but a trifling deduction from the beneficial influence of that powerful stimulus which it gives to the inventive faculties, and to that desire to improve our condition, and to mount in the scale of society, which is the source of all that is great and elevated. Hence we should strongly disapprove of any system which, like the law of equal inheritance established in France, had any tendency artificially to equalize fortunes. To the absence of any such law, and the prevalence of customs of a totally different character, we may safely attribute a considerable portion of our superior wealth and industry.

Increase of taxation.

We are also disposed to believe, how paradoxical soever such a notion may appear, that the taxation to which we have been subjected has, hitherto at least, been favourable to the progress of the country. It is not enough that a man has the means of rising in the world within his command; he must be so placed that, unless he avail himself of them, and put forth his energies, he will be cast down to a lower station. And this is what our taxation has effected: to the desire of rising in the world, implanted in the breast of every man, it superadded the fear of being thrown down to a lower place in society; and the two principles combined produced results that could not have been produced by either separately. Had taxation been carried beyond due bounds it would not have had this effect. But though considerable, its increase was not such as to make the contributors despair of being able to meet the sacrifices it imposed by increased skill and economy. And as the efforts they made in this view were far more than sufficient for their object, they occasioned a large addition to the public wealth that might not otherwise have existed.

Physical circumstances contributing to the progress of manufactures.

b. Physical circumstances contributing to the progress of Manufactures.—Supplies of the raw material may be classed among the more prominent of this description of circumstances; and those who reflect on the nature, value, and importance of our manufactures of wool; of the useful metals, such as iron, tin, lead, copper, &c.; of leather and flax, spirits and beer, and so on; will readily admit that our success in them has been materially facilitated by our possessing abundant supplies of the raw material. It is of less consequence, when the material of a manufacture possesses considerable value in small bulk, whether it be furnished from native resources, or be imported from abroad; though even in that case the advantage of having an internal supply, of which we cannot be deprived by the jealousy or hostility of others, is far from immaterial. But no nation can make any considerable progress in the manufacture of bulky and heavy articles, the conveyance of which to a distance necessarily occasions a large expense, unless she have supplies of the raw material within herself. Had we been destitute of iron ore, lead, and tin, we could never have distinguished ourselves by the magnitude and value of our manufactures of these articles. And any one who reflects on the advantages, resulting to every branch of industry from being able to procure abundant supplies of iron at the cheapest rate, will be convinced that it is no easy matter to exaggerate the obligations we are under to our exhaustless stores of that mineral.

Locke on supplies of iron.

There is a passage in Locke so applicable to this subject that it deserves to be quoted:—"Of what consequence the discovery of one natural body and its properties may be to human life, the whole great continent of America is a convincing instance; whose ignorance in useful arts, and want of the greatest part of the conveniences of life, in a country that abounded with all sorts of natural plenty, I think may be attributed to their ignorance of what was to be found in a very ordinary despicable stone—I mean the mineral of iron. And whatever we think of our parts or improvements in this part of the world, where knowledge and plenty seem to vie with each other, yet to any one that will seriously reflect on it, I suppose it will appear past doubt, that were the use of iron lost among us, we should in a few ages be unavoidably reduced to the wants and ignorance of the ancient savage Americans, whose natural endowments and provisions come no way short of those of the most flourishing and polite nations. So that he who first made known the use of that contemptible mineral, may be truly styled the father of arts and author of plenty."[2]

Supplies of coal.

But of all the physical circumstances that have contributed to our advancement in manufactures and arts, none have had so much influence as our possession of the most valuable coal mines. They have conferred advantages on us not enjoyed in an equal degree by any other people. Our extraordinary success in the manufacture of iron, copper, &c., is not owing so much to our possessing the ores of these metals, as to our possessing the coal, by the aid of which the ores have been smelted and refined. But the paramount importance of coal as a manufacturing agent has been principally manifested since the invention of the steam-engine. Without a cheap and abundant supply of fuel, the engine, as now constructed, would be of comparatively little use. It is, as it were, the hands; but coal is the muscles by which they are set in motion, and without which their strength and dexterity could not be called into action, and would be of no use. Our coal mines may be regarded as vast magazines of *hoarded* or *warehoused power*; and, unless some such radical change be made on the steam-engine as should very decidedly lessen the quantity of fuel required to keep it in motion, or some equally serviceable machine, but moved by different means, be introduced, it is not at all likely that any nation should come into successful competition with us in those departments in which steam-engines, or machinery moved by steam, may be profitably employed.

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[1] *Proposal for Amending the Trade of Holland*, printed by authority in 1756; Eng. ed., p. 12.

[2] Works, vol. i., p. 407. Ed. 1777.

Advantageous situation.

The advantageous situation of Britain for commerce, and the nature of the climate, have also powerfully contributed to the perfection of industry. Had we occupied a central internal situation like that of Switzerland, our facilities for dealing with others being so much the less, our progress would have been comparatively slow; and instead of being highly improved, our manufactures might have been still in their infancy. But being surrounded on all sides by the sea, or great highway of nations, we have been able to maintain an intercourse with the most remote as well as with the nearest countries, to supply them on the easiest terms with our manufactures, and to profit by the peculiar products and capacities of production possessed by each. With such advantages on our side, it would have been singular had we not shot ahead of most of our competitors in the race of improvement.

Climate.

Our climate is peculiarly favourable to exertion and enterprise. It admits of most sorts of labour being vigorously prosecuted, even when the thermometer is highest; while its severity, without being too great, makes comfortable clothing and lodging indispensable; and, consequently, gives rise to numerous wants that, being either unknown or little sensible in more genial climates, require proportionally greater efforts for their supply. Its inequality, too, by requiring incessant care and attention on the part of the husbandmen, makes them vigilant and active as well as laborious; and the qualities that are thus naturally impressed on this great class are, through their example, universally diffused.

But despite what has been stated above, we are disposed to believe, how unphilosophical soever it may seem, that a good deal in the history of industry must be ascribed to chance, or to some lucky accident. Had Hargreaves, Arkwright, Watt, and Wedgwood not existed, or been born abroad, it is impossible to say how much it might have affected the state of industry here and elsewhere; but there appear to be sufficient grounds for thinking that it would have been at this moment materially different from what it actually is. A good deal, too, depends on priority. A country, town, or district, that has already established and made a considerable progress in manufactures, acquires, in consequence, an advantage that may enable it successfully to contend with competitors placed under what are naturally more favourable circumstances. But these are matters that will be noticed afterwards.

It seems to be the peculiar good fortune of England that, as respects all the great branches of manufacture, she has at once the advantages of priority and of acquired skill and dexterity on her side, as well as the natural advantages already noticed of abundant supplies of the raw material, of inexhaustible beds of coal, and of situation. Cotton is not an exception; for, though the raw material be the product of other countries, the freight upon it is not very considerable, and is but a trifling deduction from the other circumstances that seem to insure our superiority in its manufacture.

Machinery.

It may be said, perhaps, that in thus briefly enumerating what seem to be principal causes of the superiority to which Great Britain has attained in manufactures, we have omitted to notice that which many reckon the most important of them all, viz., the comparative excellence of our machinery. But the production of machinery is itself a branch of manufacture, success in which depends on the same circumstances that determine success in other branches. The manufacture of machinery is, however, in so far peculiar, that superiority in it conduces, more directly than superiority in anything else, to the improvement of all descriptions of manufacture. Machines are the tools or instruments by which most industrious undertakings are either partly or wholly carried on. And hence it is, that while a marked superiority in various branches of industry may exist, where machinery is defective, simultaneously with great inferiority in others, this is hardly possible where it is highly improved. Eminence in machine-making is almost sure to lead to eminence in every other department, and is the best means for securing their advancement.

Our superiority in the manufacture of machinery depends principally on the greater intelligence of our work-people, and our unlimited supplies of coal and iron. The latter is now either exclusively or largely used in the construction of ships and houses, and of a vast variety of instruments and articles that were formerly either wholly or in great part made of wood; and their efficiency and cheapness have been in consequence very greatly increased. The steam-engine, which is made entirely of iron, performs for us the work of many hundreds of thousands of men, and of many hundreds of thousands of horses; and while it performs most part of this work incomparably better than it could have been performed by men and horses, it saves a vast amount of toil and suffering. The slavish occupation of thrashing out corn is now wholly performed by thrashing-mills, which are mostly moved by steam; and at the same time that the employment of locomotive engines on railways has added greatly to the security of travelling, and make it be performed with a speed inferior only to that of lightning, it has terminated that over-exertion which the noblest of the lower animals were formerly compelled to make in the running of stage-coaches. It is impossible, in truth, to over-rate the advantages man owes to machinery; and the idea that it may be too much perfected or extended, is the most futile and absurd that can be imagined.

Besides the great discoveries—such as the introduction of the spinning-frame, the steam-engine, and the power-loom, which suddenly change the whole aspect and economy of industry, a variety of minor improvements are always being introduced, which, though separately they may be little attended to by careless observers, have in the aggregate a powerful influence. The economizing of power, the production of the same or better articles at less expense, the substitution of cheaper or more efficient, for dearer or less efficient labour, and so forth, are objects ever present to the mind of the intelligent manufacturer; and the advance made in them in the course of a few years is usually very great.

The late improvements in the steam-engine may be referred to as affording a striking illustration of what has now been stated. For a lengthened period after it came from the hands of Watt it remained nearly stationary. But during the last twenty, and more especially during the last ten years, many important innovations have been made, by driving the engines with greater speed, enlarging the capacity and improving the form of the boilers, and so on; the result being, that from the same weight of steam machinery we now obtain, at an average, at least 50 per cent. more work than formerly; and that, in many cases, the identical engines that yielded fifty horse power, are now yielding upwards of 100 horse power, with little or no increase of expense.[1]

Exportation of machinery.

The manufacture of machinery for exportation is now become a large and rapidly increasing business. This is evident from the following account of the declared value of the exports of machinery from 1842 down to 1856, viz.:—

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[1] Letter of Mr Nasmyth of Patricroft, near Manchester, an eminent engineer, in one of Mr Horner's Reports for 1852.

Years.	Value.	Years.	Value.
1842	L.554,653	1850	L.1,042,167
1843	713,474	1851	1,168,611
1844	776.255	1852	1,251,360
1845	904,961	1853	1,985,536
1846	1,117,470	1854	1,930,860
1847	1,263,016	1855	2,211,215
1848	817,656	1856	2,717,572
1849	700,631		

It has, however, been frequently contended, and by parties not otherwise opposed to the freedom of trade, that in permitting the exportation of machinery we act unwisely; and in fact furnish our rivals in other countries with the principal instruments of our manufacturing superiority. But though specious, this statement is not entitled to much weight. It is not in our power, even if we attempted it, to enforce a monopoly of our improved machinery. The plans and patents according to which it is made, are published and sold to all who choose to buy them, whether natives or foreigners. And not only this, but English engineers, and the artizans by whom machines are made, are met with in every civilized country. All, therefore, that we should effect by prohibiting the exportation of the latter, would be the suppression of a large and lucrative branch of business; while, by forcing the foreigners to construct that machinery and mill-work for themselves, which they now buy from us, we should stimulate their invention, and endanger our ascendancy in a department which is not likely to be disturbed so long as we abide by our present policy.

II.—DISADVANTAGES SUPPOSED TO ATTEND MANUFACTURING EMINENCE.

Supposed disadvantages of manufactures.

The above seem to be the principal circumstances which have contributed to the rapid growth of manufactures in Great Britain. This growth has not, however, been always regarded as advantageous. On the contrary, many eminent authorities have doubted whether the great extension of the manufacturing system be not accompanied with so many drawbacks as go far to countervail its beneficial influence.

Introduction of machinery.

It is, for example, alleged, that of the improvements which contribute so greatly to the extension of manufactures, some are occasionally productive of injury to the work-people. But it may be easily shown that this allegation is not worthy of much attention. The inconveniences which sometimes attend the introduction of improved machines and processes are merely temporary. If by an improvement in the manufacture of hats, or any other cause, the cost of their production were reduced a half, it is probable that the wages of the hands now engaged in the hat trade would be reduced, and that some of them would be dismissed. A little consideration will, however, make it evident that these disadvantageous results cannot fail of being very soon obviated; for, as those who formerly paid 10s. or 20s. for hats, will now only pay 5s. or 10s., they will have so much more to expend on other things. The demand for produce of one sort or other will not, therefore, be diminished; and the result will be, first, that hats being cheaper, more of them will be demanded; and, second, that a part of the money formerly laid out on them will henceforth be laid out on other things, the manufacture of which will give full employment to the artizans thrown out of the hat trade. Hence, in the end, it will be found, that while everybody is supplied with hats at half their former cost, not one individual will be deprived of employment, or have his wages reduced. And such is the invariable result of all improvements in the arts, and of the opening of markets whence produce may be imported at a reduced price.

But short as this statement is, it was hardly necessary to show that improvements in machinery cannot really injure the labourer. To be satisfied of this, we have only to cast a rapid glance at the progress of the greatest of our manufactures. So late as 1760, not more, perhaps, than 3000 or 4000 persons were dependent in Great Britain on the cotton manufacture, which was so trifling as scarcely to attract any notice. But such and so vast has been the change in the interval, that the cotton trade is now, next to agriculture, the most important branch of industry carried on in the kingdom, furnishing the means of subsistence to from 1,250,000 to 1,500,000 persons. And to what but the improvement and extension of machinery are we indebted for this result, which has no parallel in the history of industry? The inventions and discoveries of Arkwright, Watt, Compton, Cartwright, and others, have created this all but boundless field for the employment of capital and work-people. The more efficient the machinery introduced the greater has been the demand for fresh supplies of labour; and such will necessarily be the result in all similar cases in all time to come.

In the course of its marvellous progress, some departments of the manufacture have come to be carried on by wholly different agents. Hand-spinning, whether by the common wheel or the jenny, has entirely disappeared; and hand-loom weaving is fast approaching its termination. And though its long agony has entailed many privations on a large number of persons, it should be borne in mind that the condition of the weavers, owing probably to the facility with which the business was learned, has never been prosperous. Luckily, they are now being rapidly absorbed into other businesses; and there cannot be a doubt that the final extinction of the class will be of especial advantage to the labourers.

The following table exhibits an account of the number of power-looms in 1836, 1850, and 1856:—

Fabric.	1836.	1850.	1856.
Cotton	108,751	249,627	298,847
Woollen	2,150	8,439	14,453
Worsted	2,969	32,617	38,956
Silk	1,714	6,092	9,260
Flax	209	3,670	7,689
Total	115,793	301,445	369,205

The rapid increase in the number of power-looms employed in the linen trade has been in great measure owing to their extended use in Ireland. This has been accelerated by the rise in the price of labour consequent on the potato rot and the emigration; but it would have taken place, though not, perhaps, so soon, independently of these circumstances. Notwithstanding the cheapness of labour in Ireland, the flax manufacture made no real progress in it till yarn was spun in factories; and the substitution of power-looms for hand-looms originates in the same cause,—in the wish to profit by the cheaper and more efficient service rendered by improved machinery. (See POST.)

Except in anomalous cases, like that of hand-loom weavers, the difficulties to which work-people are subjected in moving from a department to which they have been accustomed, when their services are no longer required in it, are more apparent than real. Many departments of industry are closely allied, and all of them have many things in common; so that an industrious and intelligent workman who is thrown out of one has seldom much difficulty, provided he be so disposed,[1] in finding his way into some other department. And it is also to be observed, that improvements are seldom so rapidly introduced as to occasion the dismissal of hands; the necessary change being usually effected by the check given to the entrance of new hands into the business.

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[1] This qualification must not be lost sight of. The disinclination of the hand-loom weavers to abandon an employment in which they are to a considerable extent their own masters, has done much to prolong the period of their transition.

But it is needless to insist farther on these points. The principal objections to the extension of manufactures depend on other considerations; and do not all admit of so conclusive an answer as those which refer to the improvement and extension of machinery.

Influence of factory labour on the intelligence and health of the work-people.

The fact of their being crowded together has been said to be exceedingly injurious to the work-people engaged in factories; and that, from their attention being constantly restricted, in consequence of the extreme subdivision of labour, to some very limited or petty operation, and the want of free air and proper exercise, they degenerate, both intellectually and physically, and become inferior to the agriculturists, and those who prosecute their business in the fields. But these consequences, though at first sight they seem to follow naturally from the circumstances, have happily not been realized, in so far, at least, as respects the mental powers of the work-people. Instead of becoming more contracted, their intellectual capacities seem, on the contrary, to have expanded with the greater subdivision of their employments. And how unexpected soever this result may be, it is, after all, only what a less prejudiced inquiry might have led us to anticipate. The many occupations which the husbandman successively carries on, and the perpetual changes in the weather, and in the growth and appearance of the objects about which he is engaged, occupy his attention, and render him a stranger to that *ennui,* and desire for external excitement, so universally felt by those employed in indoor routine businesses. This craving, on the one hand, and the few facilities for rational enjoyment on the other, is a principal cause of the dissipation in which the work-people are so prone to indulge. But it has other and less objectionable consequences. By working together, factory labourers have many opportunities, of which those employed in the fields are comparatively destitute, of discussing all manner of topics. Their intellects are sharpened by the collision of opinion. They desire to know what is going on in the world; and by each contributing a small sum, they obtain an ample supply of newspapers and other periodical publications, and sometimes form book-clubs. But whatever doubt may exist as to its cause, there can be none in regard to the superior information of the work-people employed in factories. We do not believe that they were ever less intelligent than farm-labourers. But, whatever may have been the case formerly, none will venture to affirm that they are so at present, or that they are "mere machines, without sentiment or reason." (Ferguson *On Civil Society*, p. 303.)

The objection made to manufactures on account of their alleged injurious influence over the health of the work-people in factories, is not so easily disposed of. In so far, indeed, as the question may be supposed to refer to adult males, there is no evidence to prove that factory labour, provided it be not excessive, is productive of injurious results. But it is otherwise with children, or young persons of both sexes, and perhaps also with certain classes of females. The former are never, and the latter are frequently not their own masters. And though there has been much exaggeration on the subject, still there is no room for doubt that the individuals referred to have been subjected to tasks, and confined for periods, unsuited to their age, sex, and strength. We, therefore, are disposed to approve of the policy which has been adopted of excluding children under eight years of age from factories, and of limiting the labour of young persons from eight to thirteen years of age to 6½ hours a-day, and of those from thirteen to eighteen years of age to 10 hours a-day. But we should object to any restrictions being laid on the labour of adult males, or of such adult females as are their own masters. The State is bound to protect those who cannot protect themselves; but none else. It may also, perhaps, lay down and enforce some easy regulations for the prevention of accidents in factories. But, speaking generally, the less it interferes in such matters the better. Work-people who are *sui juris* can never safely rely on the government, or on any one but themselves. The interference of the magistrate will be but a miserable substitute for that prudence and forethought which it is their duty to exercise, and which can alone secure their well-being.

Influence of factory labour on the well-being and opinions of the work-people.

Exclusive of the circumstances now mentioned, there are others connected with the growth of manufactures, in respect of which it is not easy to arrive at any definite conclusion, but which, nevertheless, deserve serious consideration. Without, however, attempting, to do more than glance at the subject, we may observe, that the tendency of manufactures appears to set strongly in favour of concentration; that is, to their being carried on in large establishments, belonging to a few great capitalists, where thousands of work-people are managed by a small number of overlookers. And in these establishments the lot of the labourers is apparently one of the least desirable. Their occupations are singularly monotonous, being little else than the endless repetition of the same set of precisely similar, and generally simple operations. It is alleged, too, that of the work-people in factories, probably not one in twenty, and certainly not one in ten, supposing they abide in them, can materially improve their condition, or rise to a higher station; and, though not the slaves of this or that master, they are, it is affirmed, the slaves of the factory system. But, while it must be admitted that these statements unhappily contain a good deal of truth, they are, notwithstanding, much coloured and exaggerated. It may be true that only a few of those employed in factories attain to independence, or even consideration; but as preferment in them, whatever may be its amount, is open to all, the great prizes which they offer, like those in a lottery, or in other occupations, attract crowds of competitors, and inspire them with a strong spirit of emulation, and with the hopes of success. In despite, however, of these and other countervailing influences, there seems, on the whole, little room for doubting that the factory system operates unfavourably on the bulk of those engaged in it. In some departments this may not be the case, but in the majority, and especially in those connected with spinning, weaving, and other merely routine employments, it is eminently so. It is certain, too, that the demand for the services of children and other young persons, and the ease with which factory labour may in general be learned, has had a powerful influence in depressing wages, and, consequently, in preventing the wonderful inventions and discoveries of the last half century from redounding so much to the advantage of the labouring classes as might otherwise have been anticipated. As compared, indeed, with the extraordinary progress made by the capitalists and employers of labour, the work-people can hardly be said to have made any very considerable advance, either in respect of their physical or moral condition. And hence the growth of unions and combinations, and of that discontent which is so very frequent among them. Their poverty, too, is rendered the more galling from the contrast which it presents to the wealth of their superiors, or of those with whom they are daily brought into contact. The latter, it is true, have generally sprung from the class to which they belong, and are mostly indebted for their greater riches to their greater genius, enterprise, and industry. But these circumstances being unknown to many, and speedily forgotten by others, they are said to owe their fortunes to chance or some lucky accident; and, except in peculiar instances, they are more generally, perhaps, regarded by those below them with feelings of envy or even ill-will, than as examples to be followed. This, of course, is not the case with the more generous, sanguine, and enterprising spirits in the workshops, who occasionally raise themselves to a level with their employers. But the great mass of factory work-people must be too conscious of their weaknesses and shortcomings to indulge in such anticipations. And in reality they have nothing before them but a life of continuous labour, cheered by few gleams of sunshine, and chequered principally by the recurrence of privations. Such being the case, can we wonder at the prevalence of that dissipation which is so much and so loudly complained of? On the contrary, the wonder is, that it is not a great deal more prevalent, and that discontent and disaffection are not more frequent and more widely spread.

Combinations are one of the favourite means to which work-people have had recourse of late years, to bring about an increase of wages, or a diminution of the hours of labour. But as we have already entered at considerable length, in the article COMBINATIONS, into an examination of their influence on industry and the condition of the labourer, it is needless to resume the inquiry in this place. We believe, however, that we are warranted in saying that it is very doubtful whether combinations to raise wages have ever been productive of any real advantage to the labouring classes; while it is certain that, on very many occasions, they have been exceedingly hostile to their interests.

This unsatisfactory state of things, which seems to grow necessarily out of the extension of manufactures, is apt to be seriously aggravated through the fluctuations to which they are subject from changes of fashion, the discovery of new methods of production, and the alterations which wars and other casualties not unfrequently make in commercial channels. It is true, indeed, that the extension and freedom of trade, by multiplying the relations of manufacturing and trading nations, renders them less dependent on circumstances affecting one or a few of their customers. But however much commerce may be extended, it is found that these as well as other nations mainly depend on a few countries for their principal supplies of the most necessary articles, while others afford the most advantageous outlets for their peculiar productions. A great manufacturing country is, therefore, exposed to vicissitudes to which it would otherwise be less liable; and hence, we may add, the expediency of its adopting a cautious and conciliatory course of policy, and of its avoiding unnecessary quarrels and contests with others.

If we be right in these statements, it follows that manufacturing eminence has, like many things else, its peculiar advantages and disadvantages. And though the latter are apparently of a very formidable description, they may, perhaps, be in a greater or less degree counterbalanced by the operation of circumstances of which we have not yet learned to estimate the influence.

Task-work.

The principle of association, in regard to which so much has been said, will never, we apprehend, be found to be productive of any sensible advantage to the labourers. (See on this subject the article WAGES in this work.) But it would be quite otherwise were the practice of task-work, that is, of employing labourers by the piece or job, to become more general. By exactly apportioning the reward to the skill and industry of the labourer, task-work takes away all temptation to idleness, and makes workmen put forth all their powers. The more enterprising become contractors on a small scale, as well as labourers; and from one step to another often raise themselves to independence, and sometimes to affluence. It were, therefore, much to be wished that the system should be introduced, in as far as practicable, into all sorts of industrious undertakings, but especially into those branches of manufacture in which the condition of the labourers is the least favourable. It would not fail to imbue them with new hopes and new energies; and would be constantly raising numbers of those that were most deserving to improved positions. We are indeed well convinced that nothing would do so much as the extensive introduction of task-work into factories, to dry up the existing sources of discontent; to give all classes—the servants as well as the masters—the same spirit; and to satisfy them that their interests are really identical.

Condition of females in factories.

The difficulty which females belonging to the labouring-classes experience in obtaining any more acceptable employment, is probably the principal cause that so many of them are found in factories. No doubt, however, the lightness of the labour, the little training required for its performance, and the power to leave them when one has a mind, are also powerful inducements to enter factories. But, however explained, the number of females engaged in them has increased from 195,508 in 1835 to 409,300 in 1856, of whom 25,982 were under thirteen years of age. The employment of so many females is a very important feature in factory economy, and is in many respects beneficial. It would be difficult, indeed, were the demand for their services in factories materially to decline, to provide them with other equally advantageous outlets. And yet the shutting up of great numbers of women in these establishments, and the close attention they have to give to their work, is productive of some results that are not a little injurious. Speaking generally, factory girls are very ill fitted for being housewives. They have little or no experience of their duties as such. The mill is their principal home; and however expert in the work they have to perform in it, they know little of anything else, and are most commonly ignorant, to an extent not easily to be imagined, of the arts by which their wages and those of their husbands may be best and most economically expended. The mischievous influence of this ignorance is too obvious to require being pointed out, and considerable efforts have latterly been made to lessen it by improving the education of girls, and instructing them in cookery, baking, sewing, washing, and other arts necessary to the wellbeing of their families. But though some improvement may be effected in the way now mentioned, it is, we apprehend, idle to expect that, however instructed, women employed in factories should generally make good wives and mothers. It is too much to expect that they should be able to attend at the same time to the mill and to their families. One or other is almost sure to be neglected; and the presumption is, that this will be the case with the latter rather than the former.

It is a curious circumstance that something like the factory system is now applied to the rearing of the children of the work-people engaged in factories; for receiving-houses (*creches*) are being established in the great manufacturing towns, where the mothers deposit their children on their way to the mills, and receive them again on their way back. And though in some respects a very considerable improvement, the adoption of this plan gives but a sorry idea of the state of the manufacturing population. Such, however, and so limited is the field for the employment of women in England compared with their vast numbers, that factory labour must be regarded, notwithstanding its many drawbacks, as having contributed materially to their welfare.

Duty of masters.

A great manufacturer, like a great landowner, has a vast deal in his power, and, with little loss to himself, may do, and sometimes does, a great deal of good to his work-people. The truth indeed is, that in promoting and rewarding those labourers who distinguish themselves by their industry and good conduct, and in checking, in as far as may be in his power, the idleness and vicious propensities of others, he is following a line of conduct that is highly conducive to his interests. But an enlightened and a generous master should do more than this. He should look upon his work-people as part of his family, should interest himself in their well-being, assist in providing schools for the education of their children, and forward any proper plan for improving their dwellings, for supplying them with good medical advice, and so forth. Those masters who can do much to promote the real interests of those in their employment, and who, notwithstanding, do little or nothing, lie under a heavy responsibility. They abdicate or abuse some of their most valuable privileges, and are culpable in more ways than one.

Owing to the facilities for obtaining supplies of skilled labour, and the convenience resulting from the vicinity of other establishments, factories may now, speaking generally, be more advantageously located in towns than in the country. This, however, has the disadvantage of making it comparatively difficult for the masters to inform themselves with respect to the habits and mode of life of those in their service. But this circumstance will not excuse that neglect of the interests of the work-people in towns which is so frequently evinced by their employers. The conduct of the former in the mill, the punctuality of their attendance, their cleanliness, and the way in which they perform their allotted tasks, will throw a great deal of light on their character. And those indices should not merely lead the master to advance the deserving, but it should, also, lead him to inquire into the modes of life and habits of the others. And it is not easy to estimate the influence that his advice, exhortation, and threatenings, might have over their conduct.

Whatever else education may do for the work-people, we do not believe that it will do what is expected by some; that is, that it will make factory-labourers contented with their lot. On the contrary, we are disposed to think that its effect will rather be the reverse of this, and that that will be one of its principal advantages. It is clear, indeed, that if it had the effect supposed, it would be in so far disadvantageous that it would, at one and the same time, weaken the motives for the introduction of those reforms into the factory system to which we have alluded, and impair the energies of the workmen, and their efforts to advance themselves.

It is plain, therefore, that it is no easy matter to cast the horoscope of the manufacturing system, to estimate the changes it may undergo, or its ultimate influence over the condition of those among whom it may be established. Much will depend on future contingencies, and much also on the operation of principles to which new combinations of circumstances will no doubt give rise. The hopes of some, and the fears of others, may at present predominate; but no just confidence can be placed in the speculations of either class; and the final results will be learned only by a distant posterity.

III. FACTORIES (ECONOMY OF).

Economy of factories.

By a factory, in a general sense, is understood any building or inclosure within which any branch of manufacturing industry is carried on. But in practice the term appears to be confined to buildings of an extensive description, fitted up with machinery, and suited for the prosecution of one or more branches of manufacture. Factories in which cotton is spun being mostly on a large scale, are generally called spinning mills; and others have peculiar names according to the nature of the business to which they are devoted.

The skill and judgment of the manufacturer are evinced in nothing more than in the proper construction and economy of factories. Their suitableness to the end in view, provided it be accomplished without any unnecessary expense, is one of the most important elements in manufacturing success. It may be laid down generally, that to insure this grand object, the machinery in factories should be of the best quality, and the labour to be performed distributed so that the strength and capacity of those employed may be exactly apportioned to the tasks they have to perform. And as any mistakes in regard to the selection of the individuals to be employed in factories, and more especially of those appointed to superintend the different departments, would be quite fatal to their success, we may be sure that everything that is practicable will be done to guard against their occurrence. But it would be idle to attempt to lay down any precise rules in regard to the economy of these establishments, seeing that all arrangements must be accommodated to the successive improvements in the arts, the species and command of the power to be employed, the price and supply of labour, and so forth. The extent also to which the different branches of industry may be most advantageously congregated into a single establishment, is entirely a practical question for the sagacity of the manufacturer, the solution of which must depend on its greater or less proximity to others, and a variety of other circumstances. Though the principle of the division of labour should never be lost sight of in the construction of factories, neither should it be carried to an extreme. In some very extensive and prosperous factories in the principal seats of the cotton trade, the various processes, from the carding, spinning, and weaving of the wool, to the bleaching and printing of the cloths, are carried on under the same roof. Generally, however, some of the processes that in these instances are performed in one, are distributed among different establishments.

Of late years the question in regard to the interference of the police in the construction of factories has been a good deal mooted. On the whole, we are inclined to think, that if confined within moderate and well-defined limits, it may be advantageous. In the smaller and inferior class of factories ventilation and cleanliness are apt to be neglected; and there does not appear to be any good reason why the police should not be permitted to see that these indispensable requisites for the health of the work-people are properly attended to, and to denounce their neglect. They may also be authorized to see that any peculiarly dangerous machine is properly fenced off, and to denounce or abate whatever can be fairly considered as a nuisance. But here, as in the case of the labourer, non-interference should be the rule, and interference the exception. The latter, indeed, is to be tolerated only when there is clear and unquestionable abuse.

Latterly it has been attempted to make factories consume their own smoke; but though this may be an expedient proceeding in the case of factories in towns or populous neighbourhoods, it is otherwise with those in the country or in thinly-peopled districts. There the smoke can do little or no injury.

Domestic manufactures.

Various branches of manufacture have, at one time or other, been wholly or partly carried on in the houses of the work-people. This was formerly the case with the spinning and weaving of wool, flax, &c., and it still continues to a considerable extent in the former department. These domestic manufactures, as they have been called, were supposed to be peculiarly advantageous, from their enabling the parties engaged in them to live in the country, away from the physical and moral contagion of great towns, and where they could now and then engage in the healthy labours of agriculture. But there was a good deal more of imagination than of reality in these representations. In some respects, indeed, if we look only at the labourers, the balance of advantage may have been on their side. They had, we may take for granted, in the country good air and good water; but at the same time their cottages have generally been of the meanest description; their children, who were made to assist their parents at the earliest possible moment, had seldom any opportunity of being educated; and the work-people themselves have most frequently been idle and slovenly. The attempt to combine the pursuits of husbandry with those of manufactures, or to assign to those engaged in the latter small portions of land which they were to cultivate at extra hours, has had the precise result that was to be anticipated; whether in England, Ireland, or elsewhere, it has proved to be a failure, and has been injurious alike to both departments. Before spinning mills were so much as thought of, and the linen trade of Ireland was wholly domestic, Arthur Young said,—"If I had an estate in the south of Ireland, I would as soon introduce pestilence and famine as the linen manufacture upon it." (*Travels in Ireland*, part ii., p. 120, 4to edition.) There cannot, in fact, be any material improvement either in agriculture or manufactures till they are separated and apportioned to entirely different sets of individuals. A good ploughman cannot be also a good artizan. Inferior workmen may engage indiscriminately in different occupations; but to attain to excellence in any one art or calling, it is indispensable that it should be the exclusive business of those by whom it is carried on. And such being the case, none need regret that the mixing up of agriculture and manufacturing employments has ceased to be regarded as favourable, and is now generally abandoned.

Still, however, certain varieties of what may be called domestic manufactures, or manufactures carried on in separate establishments on a small scale, continue to exist in a few circumscribed localities. Thus, the spinning and weaving of woollen yarn and cloth by power not being so extensively practised as in the cotton trade, the old hand-jenny and the hand-loom are in pretty extensive use in the district of which Leeds is the centre; and there, consequently, a variety of domestic manufacture keeps its ground. The parties by whom it is carried on have generally from two to six or more looms, and employ, besides their own families, more or fewer journeymen, according to the magnitude of their business. Formerly they were in the habit of carrying the wool in these little factories through all its stages, till it arrived at the state of undressed cloth. But for a considerable time past the domestic and factory systems have been so intermixed, that some of the processes in the manufacture are performed at public mills constructed for that purpose, but the cloth is almost wholly dressed and packed in Leeds.

Should the spinning and weaving of wool by power come to be perfected to the same degree as the spinning and weaving of cotton, the domestic manufacture now referred to will have to be abandoned; and this result is taking place. The processes for the spinning of wool by machinery are being perfected, and the number of power-looms employed in the weaving of wool has increased from 2045 in 1835 to 9439 in 1850, and 14,453 in 1856. The presumption consequently is, that the factory system is destined to become as preponderating in this as in other departments. The period of transition will, of course, be longer or shorter according to the progress of invention, the rate of wages, &c.; but of the transition being effected in the end, there can be no reasonable doubt.

Some departments of the hardware trade are also prosecuted in cottages, but they are of little importance. None but the simplest descriptions of machinery can be introduced into cottages or small establishments. Whenever, therefore, it is found that the work executed by their assistance may be executed more cheaply or better by means of more powerful and complex machinery, the former necessarily begin to be abandoned. And it is fortunate that their abandonment is attended by few or none of the mischievous effects by which it was formerly supposed it would be accompanied.

Domestic manufactures in Russia, &c.

Perhaps it is hardly necessary, seeing that this book is intended for the special use of Englishmen, to state that these conclusions, how applicable soever to Great Britain, France, the greater part of the United States, and other countries similarly situated, do not apply to countries with a severe climate, or to such as are very thinly peopled. In Russia, British America, Oregon, &c., the ordinary pursuits of agriculture can only be carried on for about five or six months in the year, or perhaps less, so that the peasants, if they did not engage in other employments while the land is covered with snow or bound by frost, would be idle for more than half their time. Hence in such countries the apportionment of employments to different individuals cannot be carried to anything like the extent to which it may be carried in more temperate climates; and the person who for one portion of the year is a farm labourer, is during the other portion a weaver, a carpenter, a smith, a shoemaker, or something, or, it may be, several things else. The peculiar situation of Russia makes this system be practised to a very great extent in that empire. The peasants are all artizans of one sort or other as well as husbandmen, and hence the surprising facility with which they turn from one thing to another.

In Russia, Hungary, Poland, and all imperfectly civilized countries, the cottages of the peasantry are not distributed over the surface, as in Britain, but are congregated into hamlets or villages. And it is a curious fact that these villages, instead of being addicted to many, generally confine themselves to some one occupation, exchanging their surplus products for those of the adjoining villages at the fairs so frequent in those countries, or by the intervention of pedlars or agents travelling from place to place. There is therefore in Russia a greater subdivision of employments than might perhaps have been expected; and the system seems to be well calculated for the peculiar circumstances under which the empire is placed.[1] In those provinces where the population is thinly scattered over the surface, and the villages small and at great distances from each other, the division of employments becomes less perfect, and the manufactures which are carried on from generation to generation, usually with little change, are altogether primitive and domestic.

But though, under such circumstances it would be idle to suppose that Russia should succeed in the finer branches of manufacture, or in those required for the wealthier and more refined portion of the community, there are certain branches, such as the manufacture of coarse linen and canvas, mats, leather, &c., in which she has peculiar and important advantages. And her real interests would be best promoted by opening her ports to the free importation of those articles in the production of which foreigners have a superiority; for this would give the most effectual as well as the most natural stimulus to the export of her raw products, which are the main elements of her wealth, and to those industrial pursuits in which the superiority is on her side.

Unluckily, however, this has not been hitherto the policy of the Russian government. Spinning and weaving mills, conducted on the plan followed in England, have been established at Moscow and elsewhere in Russia. And a great variety of factories have been set on foot by the nobles in different parts of the empire, the labourers in which are the slaves of the proprietors, employed for certain periods under a sort of *corvee* or statute-labour system. But notwithstanding the wonderful aptitude of the Russian peasantry to execute the tasks allotted to them, it is not to be imagined that factories carried on by compulsory and reluctant labour should prove successful; and, in point of fact, the products made in them are at once bad and dear, while the processes continue nearly stationary. And even the best managed factories, or those which are carried on by work-people, who are free on paying an *obrok* or tax to their lords, could not support themselves were they not protected by high duties on foreign fabrics. The home demand for their productions is inconsiderable. The great bulk of the population being supplied by domestic manufactures, their only dependence must be placed on the stinted demand of the upper classes resident in the few great towns, and on the export trade. And little or no stress can be laid on the latter; for, with the exception of some inconsiderable outlets along her Asiatic frontier, the chances are ten to one that the foreign markets are already supplied with cheaper and better articles.

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[1] See *passim* the statements in regard to manufactures in the valuable works of Haxthausen and Tegoborski on Russia.

IV. LOCALITY OF MANUFACTURES.

Locality of manufactures.

The locality of manufactures depends principally on physical causes, but partly, also, on accidental circumstances. Among the former may be mentioned facility of commanding power in the shape of waterfalls or steam; proximity to the raw material, as in the case of the iron manufacture; and to the demand, as in the case of cabinetmaking, brewing, and other businesses carried on in great cities; and so forth.

Production of iron.

During the first half of last century, when the iron trade of England was of very trifling dimensions, it was partly carried on in Kent, Surrey, and Sussex,[1] not so much on account of the abundance of the ore in these counties, as of the furnaces being readily supplied with fuel from their numerous woods and copses. And notwithstanding the repeated interference of the legislature in their behalf, the woods referred to, as well as those in other parts of the kingdom, were so much exhausted in 1740-50, when the make of iron did not exceed from 17,000 to 18,000 tons a-year, that had not other means been discovered of smelting the ores, the business must have been strangled in its cradle. This contingency had, indeed, been long obvious; and in the latter part of the reign of Elizabeth, and the early part of that of James I., efforts were made, partly in the view of preventing the destruction of timber, and partly of turning small coal (which was reckoned of no value) to account, to employ the latter in the making of iron. And these efforts were so far successful, that in 1621 Lord Dudley took out a patent for the manufacture of iron by means of pit-coal, he being able to produce by his process about three tons of iron a week! But though his lordship's patent was expressly excepted from the act of 1624 (21 Jac. i., c. 3) for the abolition of monopolies, his works were destroyed by an ignorant rabble, and he was well nigh ruined by his efforts to improve and perfect an invention which has since proved to be of such transcendent utility.[2] It appears, in consequence, to have been for a lengthened period almost entirely forgotten, and in 1740 or thereabouts it was only introduced into a single work in Coalbrookdale. But since that epoch, or rather since 1760 or 1770, when it was brought into general use, the manufacture has steadily increased; and of late years its progress has been so very extraordinary, that the make, which amounted in 1830 to about 678,000 tons, amounted in 1855 to no fewer than about 3,325,000 tons! At this moment the produce of iron in Great Britain is supposed to be about equal to the produce of all other countries, including the United States. In the latter the annual make may at present (1857) amount to about 850,000 or 900,000 tons.

We may mention, in farther illustration of the extension of the iron trade, that, exclusive of the vast additional quantities consumed at home, the real value of the exports of iron and steel, wrought and unwrought, has increased as follows, viz.:—

1842	L.2,457,717
1845	3,501,895
1850	5,350,056
1854	L.11,674,675
1855	9,472,886
1856	12,986,674

Next to Lord Dudley's invention, the progress of the iron manufacture has been principally owing to the improvement of the steam-engine, the invention of the process of puddling, and the introduction of the hot blast.

It is needless, perhaps, to add, that the works in Kent and Surrey have been long abandoned, and that iron is now produced exclusively in those districts in which coal as well as iron ore is most plentiful.

The vast increase in the production of iron has been mainly occasioned by its greater cheapness, which has enabled it to be applied to a great many purposes to which it would be quite unsuitable were it much more expensive. But it is said, that this greater cheapness has led to a deterioration of the quality of iron, as well as to the increase of its supply. And such, we believe, is the case. It is not clear on what the superiority of some descriptions of foreign iron depends, whether it be the preferable quality of the ore, the use of wood as fuel, the slower processes generally followed, and the greater care taken in the manufacture. But whatever the causes may be, the fact of a superior article being produced is unquestionable. It is material, however, to bear in mind that the better article costs a proportionally higher price; and as an inferior and cheaper article such as is generally made in Great Britain, suits the great majority of purposes quite as well as the other, our manufacturers have done wisely in adapting their supply to the general demand. When superior iron is required, it can be produced on its price being paid, or it can be imported. Like any other description of produce, it may be had of all qualities and at all rates. But its manufacture in England would never have attained to anything like its present value and importance, had not cheapness, rather than excellence, been the grand object of our producers.

Restrictions on the importation of iron.

Seeing that an abundant supply of iron at a moderate price is indispensable to success in the arts, it might have been expected that those countries anxious to attain to eminence in manufactures, would not fail to adopt every means that might tend to lessen its price and increase its supply; and we incline to think that if bounties on importation were ever justifiable, it would be in the case of iron. But, by a singular inconsistency, the reverse of this usually takes place; and nothing is more common than for states to impose high duties on iron brought from abroad, or to prohibit its importation, at the very moment that they are labouring to bolster up manufactures. It is needless to dwell on the contradictory nature of such a policy; which, however, is that of France, Russia, and most other countries. Owing to the scarcity of coal, and other circumstances, their producers cannot furnish iron except at a comparatively high price; and to encourage them to persevere in a disadvantageous business, government lays heavy duties on foreign iron; or, in other words, does all that it can to raise the price and deteriorate the quality of the instruments and machines principally employed in industrious undertakings! It is said by M. Tegoborski, that owing to the restraints on its importation, the scarcity and high price of iron in Russia are such that the horses of the peasantry are seldom shod, and that their ploughs, harrows, and other agricultural implements are made wholly of wood. Whereever a *felo de se* policy of this sort is adopted, it would be idle to expect that industry should make any progress. Our ascendancy in manufactures will not be in much peril so long as it is generally acted upon.

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[1] The railings round St Paul's Cathedral were cast in Sussex.

[2] The *Metallum Martis* of Dud Dudley, Lord Dudley's son, in which an account is given of the circumstances connected with his lordship's invention and the patent, was published in 1665. Having become very scarce, it has recently been reprinted, with some additional matter illustrative of the early history of the trade.

Mills commonly situated in towns.

When Sir Richard Arkwright's inventions began to be applied to the spinning of cotton, spinning-mills were most frequently erected in situations which had a considerable command of water-power, though in other respects they might be far from convenient. But the discoveries of Watt relieved the cotton-spinners from the necessity of seeking power at the sacrifice of other advantages. And while the steam-engine enabled them to command an unvarying amount of power (which was seldom the case with water), it also enabled them to build their mills in towns and other localities where labour and other things could be procured with the greatest advantage.

The extensive employment of steam in the greater number of factories is the reason that they are now mostly found in districts where coal is abundant. Owing, however, to the greater economy in the use of coal, one ton of which is now made to furnish as much power as $2\frac{1}{2}$ or 3 tons did some years ago, and the facilities afforded for its conveyance by means of railways and steam navigation, businesses established in districts where it is wanting, may, from the better training of the work-people, and the possession of the market, be able to maintain for a lengthened period their former ascendency. But the greater cost of coal or power, or an inconvenient situation, is still, notwithstanding all that has been done to lessen it, a considerable and perpetually operating disadvantage. And the desire to escape from its influence seldom fails in the end to tempt some of those who are newly entering into the trade to establish factories where the motive power may be had at less cost. And when the example has once been set, and a population familiar with the business got together in the new locality, it will most likely be wholly transferred thither, unless, as may very possibly happen, the advantages on its side should be otherwise neutralized.

Influence of accidental circumstances in determining the locality of manufactures.

But though command of power and readiness of access be powerful requisites to the success of most manufactures, the localities in which peculiar businesses are established would seem to depend as much on accident as on anything else. Why, for example, should Manchester be the great seat of the cotton, Birmingham of the hardware, Bradford of the worsted, and Leeds of the cloth trade? We apprehend that no better answer can be given to this question than that, from accidental or inappreciable circumstances, the businesses referred to happened to be early established in these towns, and that their situation having been found to be peculiarly well fitted for the improved processes of later times, they have preserved their early superiority. Had they been situated in districts without coal, or comparatively inaccessible, their early proficiency, though it might have enabled them to struggle for a while with the greater advantages enjoyed by their competitors in other districts, would not have been sufficient to secure their continued lead, or even existence. They must, like the Kentish iron-works, have been in the end abandoned. But having the good fortune to possess, in addition to early and peculiar skill in their respective trades, all the means and appliances required to secure their further advancement, their progress has been continuous and extraordinary, and their supremacy is at present more undisputed than at any former period.

Manchester is said, in Leland's *Itinerary*, written in the reign of Henry VIII., to be "the fairest, best builded, quickest, and most populous town of Lancashire" (*Itin.* v., p. 94, edit. 1769). But Leland says nothing of manufactures; and we are indebted for the earliest notice of the cotton trade of Manchester to a tract by Lewis Roberts, published in 1641, in which he says that "the inhabitants buy cotton wool in London, which comes from Cyprus and Smyrna, which they work up into fustians, vermillions, dimities, and other stuffes."[1] But it is to be observed that the wool only of these fabrics consisted of cotton, the warp being then, and long after, formed wholly of linen yarn, which was partly brought from Ireland; and that the importations of cotton yarn and raw cotton were then, and down to a comparatively late period, quite inconsiderable. Such was the late and feeble beginning of that manufacture which an unprecedented combination of discoveries here and abroad has since so prodigiously increased.

The superiority of Birmingham in the manufacture of cutlery and hardware was as conspicuous in the days of Henry VIII. as at present. Leland says,—"There be many smithes in the towne that use to make knives and all manner of cutting tools, and many loriners that make bittes, and a great many naylors; soe that a great part of the towne is maintained by smithes whoe have their iron and sea cole out of Staffordshire." (*Itin.*, vol. iv., part ii., p. 114.)

Sheffield has been long famous for its cutlery. Chaucer says of the miller of Trumpington,—"A Sheffield whittle bare he in his hose" (*Millar's Tale*, l. 3930). Leeds and Bradford are both referred to as manufacturing towns by Leland and Camden.

Linen manufacture in Belfast and Dundee.

The growth of the linen manufacture in Belfast and Dundee, both of which are destitute of water-power and of coal, may appear perhaps to militate against the previous statements; but when rightly considered, this will not be found to be the case.

The spinning and weaving of flax was established in the farm-houses and cottages of Ulster by settlers from Scotland, in the reign of James I., and it was improved by refugees expelled from France after the revocation of the Edict of Nantes. This domestic manufacture, which has been the theme of much undeserved eulogy, was perpetuated, down to a recent period, by the continued subdivision of the land; the parcels occupied by families not being sufficient to afford them employment. While this system prevailed, it was customary for agents from Belfast and other towns to visit the country fairs and markets to buy up the raw or brown webs, which were mostly conveyed to the former, where, after being bleached, lapped, finished, and packed, they were exported partly to Britain and partly to foreign parts. In this way Belfast became the principal seat of the linen trade of Ulster, and its merchants were rendered familiar not only with the various details of the home trade, but also with the various circumstances affecting the supply and demand for linens in the countries to which they were exported.

Matters went on in Ulster nearly in the way now stated till between 1825 and 1830. In the meantime, however, the machinery that had been first applied to the spinning of cotton began to be applied to the spinning of flax; and after this had been effected, some enterprising parties, among whom the Messrs Mullholland were the first, constructed flax-mills in Belfast, with the view of supplying the cottage weavers with yarn. The speculation proved eminently successful. Precisely the same causes that had given the first great stimulus to mill-spinning in Lancashire and other parts of England were in operation in Ulster. The processes of spinning and weaving were most frequently carried on together in the same cottages; but the families of the weavers being unable to furnish them with sufficient quantities of yarn, the latter were in the habit of collecting additional supplies from spinners and others not attached to looms. A good deal of the weavers' time was thus frittered away; and being frequently idle, or only half-employed, they were apt to contract bad habits. Under these circumstances we need not be surprised to learn, that no sooner had the mill-spun yarn come into the market, than it was eagerly sought after by the weavers and their employers; and being cheaper than that spun by the common hand-wheel, and the supply regular and abundant, the latter was in no very lengthened period entirely thrown aside. Many of the families who had previously been engaged in spinning emigrated to Belfast, where they found employment in the flax-mills that were multiplied on all sides; while the greater number of those who continued in the country are now employed in the embroidery of muslins, which are sent in vast quantities to be sewed in Ulster, from Glasgow, the grand seat of the muslin trade.

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[1] "Treasure of Traffic," p. 73, in *Select Tracts on Commerce*, reprinted for the Political Economy Club in 1856.

The excellence of the bleaching in the country contiguous to Belfast is one of those circumstances to which the progress and present prosperity of its manufacture is in no inconsiderable degree to be ascribed. Whether it be occasioned by some peculiarity of the water, the humidity of the atmosphere, or the mildness of the winter, is unknown. But of the pre-eminence of Ulster in this art there can be no question. So much is this the case, that English power-loom fabrics and Belgian brown webs are regularly sent to Ulster to be bleached.

Such seem to be the main features in the progress of the linen trade of Belfast. Its situation made it the natural emporium of the business, and it had attained to eminence as such before the command of natural power was supposed to be of much consequence. Now, however, this is found to be of primary importance. And as coals for the mills must be brought from Ayrshire and Cumberland, and the machinery used in them from Manchester, these circumstances operate as a serious drawback on Belfast, and it remains to be seen whether she will be able permanently to maintain her present ascendancy. The superiority of her bleaching grounds, the skill of her work-people, who are familiar with all the details of the business, and the greater cheapness of their labour, have all helped to turn the balance in her favour. But the latter circumstance was a good deal more decided a few years since than at present; and despite its influence, the cotton-mills which were constructed previously to the flax-mills have had to be given up. It is probable, too, that the progressive employment of power-looms in the weaving of linen, into which they are already very extensively introduced, may eventually operate to the prejudice of Belfast. But in a case of this sort, where so many unforeseen contingencies may arise, little stress can be safely laid on any conclusions as to the precise results that may be expected to take place at some future period. It is plain, however, that in the present state of manufacturing industry, the disadvantages that attach to Belfast and other places similarly situated, are of a rather formidable description. They may no doubt be fully countervailed by peculiar advantages; but if not, they can hardly fail in the long run to sap the foundations of their prosperity.[1]

Most part of the statements now made with respect to the linen trade of Belfast apply with but little alteration to that of Dundee. At an early period the manufacture of coarse linens for home use and for exportation was carried on in the towns of Dundee, Arbroath, Montrose, &c., and in the villages and hamlets of the adjacent districts. Some portion of the raw material was raised at home, but by far the greater portion was imported from abroad, especially from Russia. Dundee early took the lead in this business, and became the principal centre of the trade. For a lengthened period the manufacture was bolstered up by means of bounties and prohibitions. But notwithstanding their assistance, it made but a slow progress till after mills for the spinning of the yarn were introduced. Since, then, however, its advance, despite the repeal of the bounty, has been quite extraordinary, and it is at present in a prosperous condition.

In the case of Dundee, as in that of Belfast, early acquaintance with the trade, a convenient situation for the exportation of the manufactured goods and the importation of the raw material, and a good harbour, gave her advantages of which her citizens have availed themselves with an energy and enterprise which have seldom if ever been surpassed. Still, however, the want of water-power and of a supply of native coal are considerable impediments to the progress of the manufacture; and the fair presumption would seem to be, that in the end they must have the same influence here which we have seen they may be expected to have in Belfast. It may, perhaps, be worth while to add, in corroboration of this view of the matter, that the manufacture of cottons, which was also attempted here as well as in Belfast, has long ceased to exist.

We subjoin some statements illustrative of the extent, progress, and location of the factories for the production of textile fabrics.—(*See Table on next page.*)

Cotton.

Of the 2046 cotton factories in England and Wales in 1856, no fewer than 1480 were situated in Lancashire; Manchester being the metropolis of the trade. The remaining factories were principally situated in the West Riding of Yorkshire, Cheshire, and Derbyshire.

The cotton trade of Scotland is mostly restricted to the counties of Lanark and Renfrew, and that of Ireland (which is inconsiderable) to Antrim. But while the business has of late years been very greatly extended in England, it has been nearly stationary in Scotland, and has fallen off in Ireland.

Embroidery of muslins.

The embroidery of muslins, a branch of the cotton trade which is highly deserving of attention, was commenced in Scotland about 1825, and is almost wholly carried on by Glasgow houses. It is now of first-rate importance, its increase not having been surpassed by that of any other branch of industry, and equalled by very few. At present (1857) one Glasgow house employs in its central establishment in that city no fewer than 500 men and 1500 women, besides employing from 20,000 to 30,000 females, partly in Ayrshire and other parts of Scotland, but principally in Ireland! In all, above fifty houses are engaged in the trade; and the total sum paid as wages to females in the western parts of Scotland, and in Ireland, is believed to amount to L.750,000 a-year. The embroidery is entirely executed by hand, the attempts to execute it by machinery having failed, or been found to be too expensive. The

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[1] We have been greatly indebted in compiling these remarks to a very valuable paper on this subject communicated to us by Sir James E. Tennent.

Abstract Account of the Number of Factories for Spinning and Weaving Cotton, Sheep's Wool, Worsted, Flax, and Silk, in the United Kingdom, in 1856; showing also the Number of Spindles and Power-Looms, and of the Individuals (classified according to their sexes and ages) employed in the same.—(From the Parliamentary Paper, No. 7, Sess. 1857.

Description of Factories.	No. of Factories.	No. of Spindles.	No. of Power Looms.	Amount of Moving Power.		No. of Children under 13 Years of Age.		No. of Males between 13 and 18 Years of Age.	No. of Females above 13 Years of Age.	No. of Males above 18 Years of Age.	Total Numbers Employed.		
				Steam.	Water.	M.	F.				M.	F.	M. & F.
Cotton Factories.													
England and Wales,......	2046	25,818,576	275,590	79,836	6551	14,024	9,911	36,421	182,905	97,909	148,354	192,816	341,170
Scotland, ...	152	2,041,139	21,624	7,641	2330	339	374	2,096	26,715	5,174	7,609	27,089	34,698
Ireland, ...	12	150,502	1,633	524	250	...	...	424	2,122	799	1,223	2,122	3,345
Total,.........	2210	28,010,217	298,847	88,001	9131	14,363	10,285	38,941	211,742	103,882	157,186	222,027	379,213
Woollen Factories.													
England and Wales,......	1282	1,499,949	13,726	16,265	6261	3,742	2,914	9,828	25,918	26,728	40,298	28,832	69,130
Scotland, ...	196	272,225	665	1,197	1746	31	15	1,232	4,323	3,679	4,942	4,338	9,280
Ireland, ...	27	14,798	62	28	404	1	...	74	338	268	343	338	681
Total,.........	1505	1,786,972	14,453	17,490	8411	3,774	2,929	11,134	30,579	30,675	45,583	33,508	79,091
Worsted Factories.													
England and Wales,.. ...	511	1,298,326	38,819	13,180	1301	4,828	6,398	7,061	50,540	17,863	29,752	56,938	86,695
Scotland, ...	8	21,137	135	290	34	...	2	41	656	196	237	658	890
Ireland, ...	6	5,086	2	3	96	...	...	14	175	20	34	175	
Total,.........	525	1,324,549	38,956	13,473	1431	4,828	6,400	7,116	51,371	18,079	30,023	57,771	87,794
Flax Factories.													
England and Wales,......	139	441,759	1,987	3,639	1005	683	584	1,932	13,037	3,551	6,166	13,621	19,787
Scotland, ...	168	278,304	4,011	5,529	817	118	308	3,174	23,083	5,039	8,331	23,391	31,722
Ireland,.......................	110	567,980	1,691	5,219	2113	52	61	3,844	19,743	5,053	8,949	19,804	28,753
Total,.........	417	1,288,043	7,689	14,387	3935	853	953	8,950	55,863	13,643	23,446	56,816	80,262

						Number of Children.									
						Under 11 Years of Age.		Between 11 & 13 Years of Age in Silk-Throwing Mills.							
Silk Factories.															
England, ...	454	1,063,555	9,260	4,238	816	719	966	1946	4295	4,069	33,300	10,005	16,739	38,561	55,300
Scotland, ...	6	30,244	...	122	...	...	1	7	153	37	523	116	160	677	837
Ireland, ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total,.........	460	1,093,799	9,260	4,360	816	719	967	1953	4448	4,106	33,823	10,121	16,899	39,238	56,137

GENERAL SUMMARY.

Total Number of Factories.	No. of Factories.	No. of Spindles.	No. of Power Looms.	Amount of Moving Power.		Children under 13 Years of age attending School.		Number of Children between 11 & 13 Years of Age in Silk-Throwing Mills.		No. of Males between 13 & 18 Years of Age.	No. of Females above 13 Years of Age.	No. of Males above 18 Years of Age.	Total Numbers Employed.		
				Steam.	Water.	M.	F.	M.	F				M.	F.	M. & F.
England and Wales,	4432	30,122,165	339,382	117,158	15,934	23,996	20,773	1946	4295	59,311	305,700	156,056	241,309	330,768	572,077
Scotland, ...	530	2,643,049	26,435	14,779	4,927	488	700	7	153	6,580	55,300	14,204	21,279	56,153	77,432
Ireland, ...	155	738,366	3,388	5,774	2,863	53	61	...	...	4,356	22,378	6,140	10,549	22,439	32,988
Total of United Kingdom, ...	5117	33,503,580	369,205	137,711	23,724	24,537	21,534	1953	4448	70,247	383,378	176,400	273,137	409,360	682,497

webs to be embroidered pass between engraved cylinders, driven by steam-engines, which mark in faint lines the embroidery to be executed, and they are then sent to agents, who distribute them among the peasantry, who are paid by the piece, or job. It is not easy to exaggerate the advantages resulting to the female part of the population from this employment. After being embroidered, the webs are returned to Glasgow, where they are bleached and dressed, and sometimes made up into different articles. A large proportion of the goods are exported to the United States and Canada.[1]

The value of the exports of all sorts of cotton goods and yarn in the undermentioned years has been as follows, viz.:—

	1842.	1850.	1856.
Cotton goods,	L.13,907,884	L.21,873,697	L.30,219,099
Yarn,.........	7,771,464	6,383,704	8,065,671

The subjoined table, taken from the carefully-compiled and comprehensive statement of Messrs Holt and Company of Liverpool, dated 31st December 1856, shows in a very striking manner the progress and principal circumstances connected with the cotton manufacture since 1816:—

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[1] We are indebted for most part of this information to our learned and excellent friend, Dr Strang, chamberlain of Glasgow.

Statement of the Imports into, the Exports from, and of the Consumption, Prices, &c., of Cotton Wool in, Great Britain, in different Years, from 1816 *to* 1856, *both inclusive.*

Average Weekly Consumption.	1816.	1820.	1830.	1835.	1840.	1845.	1850.	1854.	1855.	1856.
Upland	...	2,918	5,452	5,896	5,346	7,243	4,450	5,731	7,809	5,681
Orleans and Alabama	990	1,192	4,756	7,823	13,854	17,169	15,788	23,452	21,919	24,948
Sea Island	...	409	460	354	392	392	529	427	550	662
Total United States	4,036	4,519	10,668	14,073	19,592	24,804	20,767	29,610	30,278	31,291
Brazil	1,589	2,408	3,602	2,339	1,444	2,192	3,310	1,925	2,198	2,798
Egypt	...	...	508	446	540	1,062	1,542	2,100	2,359	2,457
East Indies	207	1,518	940	1,069	2,227	1,888	3,385	3,996	5,383	5,181
Demerara, West India, &c	656	534	284	421	260	331	121	198	185	260
Total	6,488	8,979	16,002	18,318	24,063	30,277	29,125	37,829	40,403	41,987
Packages annually consumed	337,400	466,900	832,100	954,100	1,251,300	1,574,400	1,514,500	1,967,100	2,101,000	2,183,300
Aver. weight of packages consumed in lbs.	263	258	298	333	367	385	388	394	399	408
Weekly consumption in packages, average 408 lbs.	5,603	7,786	13,636	15,327	21,643	28,571	27,697	36,531	39,512	41,987
Average weight of packages imported, in lbs.	256	249	300	331	365	386	392	408	396	414
Packages exported	29,300	23,400	33,400	102,800	119,700	122,800	271,800	316,600	316,900	358,700
Lbs. weight annually imported in millions and tenths	93·9	143·9	261·2	561·7	583·4	716·3	685·6	886·6	901·1	1021·
Lbs. weight consumed ditto	88·7	120·3	247·6	318·1	458·9	606·6	588·2	776·1	839·1	891·4
Lbs. weight in ports 31st December, ditto	19·2	110·5	91·4	73·3	162·9	400·8	194·1	329·6	177·4	130·
Lbs. weight in Great Britain, ditto	...	127·0	118·8	89·6	207·0	453·5	231·6	271·2	208·9	196·2
Average price per lb. of Uplands in Liverpool	18¼*d.*	11½*d.*	6·9*d.*	10¼*d.*	6*d.*	4⅜*d.*	7¼*d.*	5⅜*d.*	5¾*d.*	6*d.*
Ditto, ditto, Pernams	26*d.*	15½*d.*	8¼*d.*	14·1*d.*	9¼*d.*	6⅜*d.*	7⅞*d.*	7*d.*	7*d.*	7⅛*d.*
Ditto, ditto, Surats	15⅛*d.*	8½*d.*	5*d.*	7½*d.*	4⅝*d.*	3*d.*	5⅛*d.*	3½*d.*	3⅞*d.*	4⅜*d.*

N.B.—Messrs Holt and Co. estimate the average weight of the packages imported in 1856 at 423 lbs. per bag Upland; 454 lbs. Orleans and Alabama; 330 lbs. Sea Island; 181 lbs. Brazil; 308 lbs. Egyptian; 385 lbs. East Indian; and 175 lbs. West Indian.

Wool.

Of the 1282 woollen factories in England and Wales, 807, or nearly two-thirds of the whole, belong to Yorkshire. The trade has for some years past been increasing very rapidly in the West Riding, while it has been declining in most other parts of the kingdom.

Worsted.

The worsted manufacture, which has latterly been very greatly increased, is principally concentrated in Yorkshire, Bradford being its centre. Recently, however, a considerable number of worsted factories have been constructed in Worcester.

We borrow from the report of the jury on woollen and worsted manufactures in the Great Exhibition of 1851, the following details illustrative of the progress of the trade in Bradford:—"The first factory in Bradford was built in 1795; but it was not until thirty years afterwards that the power-loom was introduced, and considerably later before its use became general. From the year 1825 the worsted manufacture has made most rapid and unprecedented progress. Up to that period, and for some years afterwards, all the goods were made from wool alone; but about the year 1834 manufactures of worsted weft and cotton warp were first brought forward, and gave a great impetus to the trade. This was still further increased by the introduction in 1836 of the wool of the alpaca, an animal of the llama tribe, inhabiting the mountain ranges of Peru. Considerable difficulties were at first experienced in the working of this material; but they were ultimately overcome, and the alpaca manufacture now ranks as a very important branch of the worsted trade. About the same time, or shortly afterwards, mohair, or goat's wool, from Asia Minor, was brought into general use in the West Riding of Yorkshire, and many beautiful fabrics were produced from it. Silk also, in combination with wool, alpaca, and mohair, has been largely used. Improved machinery has been devised; more rapid processes of manufacture adopted; and the results of all these improvements, and the introduction of these new materials have been—the opening of new branches of industry, the quadrupling within thirty years of the number of work-people employed, and the production of an immense variety of fabrics for the purposes of clothing and furniture.

"The rapid progress of the trade may be illustrated by a reference to the town of Bradford, which is the centre of the manufacture, and the great market where its productions are disposed of. The population of the borough has increased in the following ratio, viz.:—

In 1801 it was	13,264
„ 1821 „	26,309
„ 1841 „	66,718
„ 1851 „	103,782

"At the beginning of the present century there were only three mills in Bradford; there are now (1851) upwards of 160.

"The following returns show the extent of its present manufacturing operations. They comprise the parish of Bradford and the village of Bingley:—

Number of spindles	355,792
Number of power-looms	17,294
Moving power, steam (horse-power)	3,884
Do. water do.	134
Children employed under 13 years of age,—Males	1,469
Do. do. Females	1,729

Males from 13 to 18	3,426
Do. above 18	5,951
Females above 13	21,280
Total persons employed—Males	10,846
Females	23,009
Total	33,855"

And since 1851 the progress of the manufacture has been quite as rapid as previously.

On the whole, it appears that the total number of persons employed in the worsted factories in Bradford had increased in the interval between 1835 and 1854 no less than 384 per cent.[1] It is worthy of notice, too, that the demand for adult labour has been proportionally greater than for juvenile labour, that is, for hands under eighteen years of age. This result is believed to be owing partly to adults being exempted from the statutory regulations in regard to factory labour, and partly to the more extensive use of highly improved machinery.

Flax.

Yorkshire is also the principal seat of the English flax trade; but the business has been for several years in a backward state in England. At present (1857) it is more vigorously prosecuted in the parts of Ireland adjacent to Belfast than anywhere else in the United Kingdom.

Silk.

Since 1850 the manufacture of silk has increased more rapidly than that of any other textile fabric. It belongs almost wholly to England, and principally to the counties of Chester, Derby, and Lancaster.

The great improvement and extension of this manufacture of late years is particularly deserving of attention, inasmuch as it affords a very striking illustration of the advantages of competition. Previously to 1826 the importation of foreign silk goods was prohibited, and an enormously high duty was laid on foreign thrown silk. The consequences were such as might have been anticipated. The manufacturers and throwsters, trusting to the protection thus unwisely given to them, made no effort at improvement, and instead of taking the lead, like their neighbours, in most other businesses, they were far behind their foreign rivals. In consequence, the manufacture was limited in the extreme; the parties engaged in it were every now and then subjected to the severest vicissitudes; and the smuggling of foreign silks, despite all that could be done to prevent it, became a flourishing business. At length, in 1826, Mr Huskisson, struck with the evils of this state of things, determined to abate them by introducing an entirely new system, that is, by allowing foreign silks to be imported at a duty of 30 per cent. *ad valorem*, and reducing at the same time the duties on raw and thrown silk. And notwithstanding the many confident predictions to the contrary, the trade has since continued progressively to extend itself on all sides. The manufacturers, seeing they could no longer depend for support on custom-house regulations, became aware of the necessity of exertion; old and worn-out machinery was replaced by the newest and most improved; processes were simplified and perfected; and it is admitted on all hands that the manufacture made greater advances between 1826 and 1840 than it had done in the course of the previous century.

In 1845 Sir Robert Peel reduced the 30 per cent. *ad valorem* duty on foreign silks when imported to 15 per cent.; and while this wise and liberal measure went far to suppress the smuggling that previously prevailed, it gave a new stimulus to the invention and ingenuity of the manufacturers. The business has in consequence been very largely extended; so much so, that the value of the exports of silk goods, which in 1842 amounted to only L.590,189, had increased in 1856 to L.2,966,938,—a memorable and signal example of the powerful and beneficial influence of that free commercial policy which Sir Robert Peel did so much to introduce.

Exclusive of the return of factories, &c., previously referred to, similar returns were obtained in 1835, 1838, and 1850. The following comparative statements deduced from these returns show the progress of the factory system in so far as it applies to textile fabrics since 1838:—

Number of Factories in the United Kingdom in 1838, 1850, *and* 1856, *exhibiting their Increase per cent. from* 1838 *to* 1856.[2]

Description.	Factories in			Per cent. increase from 1838 to 1856.
	1838.	1850.	1856.	
Cotton Factories...	1819	1932	2210	21·495327
Woollen „ ...	1322	1497	1505	13·842662
Worsted „ ...	416	501	525	26·201923
Flax ...	392	393	417	6·377551
Silk ...	268	277	460	71·641791
Total ...	4217	4600	5117	21·342186

N.B.—A return was obtained of the number of factories in 1835, but being evidently incomplete, no good purpose would be served by quoting it.

Inasmuch, however, as the size and efficiency of factories has been greatly increased since 1838, the mere increase of their number affords no just criterion of their increased capacity of production. This will be evident from the following returns:—

Account of the Horse Power, distinguishing between Steam and Water, employed in the Factories of the United Kingdom in 1838, 1850, *and* 1856, *with their increase per cent, from* 1838 *to* 1856.

Material.	Horse Power in									Per cent. increase from 1838 to 1856.
	1838.			1850.			1856.			
	Steam.	Water.	Total.	Steam.	Water.	Total.	Steam.	Water.	Total.	
Cotton...	46,826	12,977	59,803	71,005	11,550	82,555	88,001	9,131	97,132	62·419455
Woollen...	11,525	9,092	20,617	13,455	8,689	22,144	17,490	8,411	25,901	25·629335
Worsted...	5,863	1,313	7,176	9,890	1,625	11,515	13,473	1,431	14,904	107·692307
Flax...	7,412	3,677	11,089	10,905	3,387	14,292	14,387	3,935	18,322	65·226801
Silk...	2,457	927	3,384	2,858	853	3,711	4,360	816	5,176	52·955082
	75,083	27,926	102,069	108,113	26,104	134,217	137,711	23,724	161,435	58·162615

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[1] Report of Mr Redgrave, factory inspector, October 1854.

[2] These returns are taken from the Report of the inspectors of factories for the half year ending 31st October 1856, but we have added the column of per centages.

Account of the Total Number of Persons employed in the Factories of the United Kingdom in 1835, 1838, 1850, *and* 1856, *with their Increase per cent. from* 1838 *to* 1856.

Fabric.	Hands employed in				Per cent. increase from 1838 to 1856.
	1835.	1838.	1850.	1856.	
Cotton ...	219,386	259,104	330,924	379,213	46·355517
Woollen..	55,461	54,808	74,443	79,091	44·305575
Worsted..	15,880	31,628	79,737	87,794	177·583154
Flax......	33,212	43,557	68,434	80,262	84·268889
Silk.......	30,745	34,303	42,544	56,137	63·650409
Total ...	354,684	423,400	596,082	682,497	61·194378

Bringing these proportions together, we have the following

Account, exhibiting the Increase per cent. in the Number of Factories in the United Kingdom, and in the Amount of the Power used and the Number of Hands employed in them, from 1838 *to* 1856.

Fabric.	Increase per cent. 1838 to 1856.		
	Factories.	Power.	Hands.
Cotton	21·495327	62·419945	46·355517
Woollen......	13·842662	25·629335	44·305575
Worsted......	26·201923	107·692307	177·583154
Flax	6·377551	65·226801	84·268889
Silk	71·641791	52·955082	63·650409

These accounts set the increasing size and efficiency of factories in the clearest light, and strikingly illustrate the statements already made in regard to their tendency to increase. Notwithstanding the apparent contradictory nature of the allegation, the truth is, that the factory system may in reality be increasing when the number of factories is diminishing. Thus in Scotland the number of cotton factories fell off from 192 in 1838 to 152 in 1856, while the horse-power employed in them rose during the same interval from 8340 to 9971.

At an average of the United Kingdom, the number of spindles in a factory was,—

	In 1850.	In 1856.
Cotton..............................	14,000	17,000
Worsted............................	2,200	3,400
Flax	2,700	3,700

The average number of spindles kept in motion per horse power was—

	In 1850.	In 1856.
In cotton factories..................	275	315
Worsted..............................	86	102

In woollen and flax factories the proportions were nearly the same.

Weaving factories have been supposed to form an exception to the tendency to the concentration of the business in large establishments. But this result is apparent only, and is occasioned by the extensive introduction of power-looms into the worsted, flax, and silk trades, the factories for which are not upon so extensive a scale as those for cotton-weaving, to which they were first applied.

Regulations in regard to the quality of manufactured goods.

It is perhaps hardly necessary to advert to the regulations intended to secure the quality of manufactured goods that were formerly so very general. These are now almost everywhere abolished; and it appears to be generally conceded that in this, as in most other things, the free competition of the producers is the only principle on which any reliance can ordinarily be placed for securing superiority of fabric, as well as cheapness. Wherever industry is emancipated from all sorts of restraints, those who carry it on endeavour, by lessening the cost or improving the fabric of their goods, or both, to extend their business; and the intercourse that subsists among the different classes of society is so very intimate, that an individual who should attempt to undersell his neighbours by substituting a showy and flimsy for a substantial article, would be very soon exposed, and be obliged to reduce its price to its proper level. Cheaper articles are often advantageously substituted for those that are dearer; but it is not possible to substitute inferior for superior articles, and maintain them in the place of the latter, without making a proportional reduction in their price. A manufacturer has not only the eyes of his customers but of the trade upon him; and while any scheme for diminishing expense excites their competition, all attempts at fraud are most commonly ruinous to the future prospects of the party. A character for honesty and fair dealing is, in the arts as in everything else, of the highest value.

Wherever public marks or regulations are introduced, their tendency is to weaken or extinguish that spirit of invention and enterprise which is indispensable to manufacturing eminence. When a man's muslins, or silks, or linens, come up to the official standard, he has no motive to improve them still more. Whereas, when there is no standard other than the public taste, he has, in the more as well as in the less advanced stages of his art or craft, the same desire to attract demand and to extend his dealings; and this he can only do by reducing the price of his goods, or suiting them still better to the real or imaginary wants of his customers or of the public.

It is obvious, too, that the plan of subjecting manufactured products to examination by government agents must lead to all sorts of abuse. When this baneful practice used to be carried on, the higher marks were frequently fixed, not to the best goods, but to those whose producers were best able to promote the interests of the examiners.

Brands in the herring fishery.

Consistently with what is now stated, we have to regret that when the bounty on herrings was repealed in 1830, government did not also abolish the "Fishery Board," and the officers and regulations it had appointed and enacted. So long as the bounty existed, it was proper that those who claimed it should be subjected to such regulations as government chose to enforce. But after its repeal, we see no reason why the fishery should not have been made perfectly free, and every one allowed to prepare his herrings as he thought best. It is said, indeed, that were there no inspection, frauds of all sorts would be practised; that the barrels would be ill made and of a deficient size; that the fish would not be properly packed; that the bottom and middle of the barrels would be filled with bad ones, a few good ones only being placed at the top; that there would not be a sufficiency of pickle, &c. But it is obvious that the reasons alleged in vindication of the official inspection which it is proposed to continue in the case of the herring fishery, might be alleged in vindication of a similar inspection in almost every other branch of industry. It is, in point of fact, utterly worthless. It is an attempt on the part of government to do that for their subjects, which they can do better for themselves. Supposing the official inspection and brand were put an end to, the different curers would have brands of their own; and it would be their object to improve and perfect the quality of their fish, that they might dispose of them more readily and at a better price. It is no answer to this reasoning to say, that at present herrings with the official brand are prefered to those without it. The fact of its having been long in use, and held forth as a guarantee of goodness, has created, without any just ground, a prejudice in its favour. But when it is abolished, and official *prestige* has ceased to influence opinion, competition will do its work. The fish of those curers that are found to be best and cheapest will be sure to be in the greatest demand; while all attempts at fraud will not fail to drive those by whom they may be made from the market. Of the many thousand barrels of pork, and the many hundreds of thousands of bales of cotton, annually exported from the United States, those that are falsely packed make an all but inappreciable fraction; indeed, such a thing is very rarely heard of. And yet no one supposes that there is any very material difference between the *morale* of the packers of pork and cotton, and those of fish. Were the official brand abolished, the latter, like the former, would very soon find that their advantage would be most effectually promoted by their fish being not only above suspicion but of the best quality.

Cases in which examination may be useful.

But though, speaking generally, the abolition of the examination system has been of the greatest advantage, there are a few departments which are so very peculiar that it may perhaps be beneficially enforced in them. Fire-arms, for example, cannot be readily tested by ordinary persons; and as any defect in their construction is most dangerous, we are disposed to agree with those who think that it would be good policy to prohibit the sale of all muskets, fowling-pieces, pistols, &c., that have not been tried and approved at a public proof-house. If a man buy a barrel of inferior herrings, or a piece of bad cambric or calico, no great harm is done, and he will not return to the shop where he was cheated. But it is quite another matter if he buy a defective fowling-piece. In this case he may lose his life as well as his money; and hence the advantage of the previous examination.

Precisely the same reasoning applies to the case of chain-cables and anchors. It is but seldom that they can be tested by the buyers. And as the safety of the ship and crew may be compromised by the cable having a single bad link, or the anchor being improperly constructed, it appears expedient that they should be subjected to an efficient test before being used.

The imposition of the stamp on plate has been defended on the like grounds; that is, on the difficulty of determining whether an article be of the standard quality or not, and the consequent expediency of affording a guarantee to the purchaser. It is, however, contended that in this case (and the same reasoning applies, though in a less degree, to the case of fire-arms and cables) the security is far from complete; and that the forgery of the stamps, and their transference from one piece of plate to another, of inferior quality, make them rather a cover to than a security against fraud. On the whole, however, we have little doubt that they are useful. The forgery of a stamp being reckoned in the public estimation a much more serious offence than the substitution of a spurious for a genuine article, the fair inference is, that it will be more rarely committed.

It is not uncommon for the brands or marks of eminent manufacturers to be adopted abroad, and sometimes even at home, and affixed to wares of an inferior character. The total prevention of practices of this sort needs not, we fear, be looked for. Still, one should think that such police arrangements might be adopted as would prevent such practices at home, and such engagements entered into with foreign countries as might go far to hinder them from becoming injuriously prevalent in those countries; more especially as it is not difficult, by the intervention of the press, to expose these mal-practices, and make them redound to the disgrace of those by whom they are adopted.

Manufacturing by government.

To begin at this time of day to argue in favour of the greater cheapness of products manufactured by individuals working on their own account, and reaping all the advantages of superior skill and economy, as compared with those manufactured by agents employed by government, may perhaps be considered a mere waste of time. In as far as authority, argument, and experience can settle a question of this sort, it has been settled a thousand times over.

And yet, how singular soever it may appear, proposals are every now and then made to governments by individuals, who are bold enough to promise that, provided they are employed for the purpose, they will engage to produce such and such articles of better quality, and at lower prices than they can be bought for in the market. And though it be natural enough to expect that such offers should occasionally be made, especially by those who have broken down in the management of their own affairs, it is, we think, not a little surprising that they should be listened to, and still more that in some cases they should be acted upon.

It is alleged in vindication of such conduct, that though the greater cheapness and efficiency of articles produced under a system of open competition be true generally, the case in question, whatever it may be, is an exception. And this is pretended to be proved by estimates of the cost of the articles to be produced, which are not really, in one case in five hundred, worth the paper on which they are written. In such estimates some most important items of expense, and some important considerations, are wholly lost sight of, or are carefully kept in the background. Thus, suppose it were proposed that a government should manufacture paper, cloth, muskets, or other articles for itself, it would be told that the raw material would cost so much, the labour so much, and that the produce could be turned out at some two-thirds or less of the sum for which it could be bought. But every one who knows anything of the matter, knows that a vast number of other items besides raw material and labour enter into the cost of manufactured goods. The mills and factories in which the articles are produced cost large sums; and the articles must be charged not only with the interest of the sums laid out in the construction of the mills, &c., but with a farther sum to insure them against fire, to keep them in working order, and to form a sinking fund to replace them when they are worn out. But this is not all. Inventions are constantly being made; so that the most efficient machinery of to-day may be the least efficient in a year or two, and must consequently be changed at whatever cost. And not only this, but the goods or articles produced in 1856 or 1857, and which were then supposed to be the best of their kind, or the most suitable for the end in view, may be in a short while superseded by others, for the production of which the machinery now in use may be totally inapplicable. And besides mills and machinery, governments which are foolish enough to enter into such undertakings must have men to work them. And what are they to do with them when they have no work on which to employ them, or when they become old, or are maimed by accident? They cannot turn them adrift; they must maintain them in one way or other; and the cost of their maintenance will be a part, and in the end no inconsiderable one, of the cost of the articles. But it is needless to insist farther on these and the many similar considerations which will occur to the reader. Those who really believe that products manufactured by government agents can be furnished as cheaply as those manufactured by private parties, may believe, on quite as good evidence, in the truth of Mormonism, spirit-rapping, or any other quackery or folly of the day.

But it is said, that though the goods manufactured by governments may not be so cheap, they will be of better quality than those made by private parties, and that there will be less chance of inferior articles being mixed with them. But we deny that such is the case. Let governments select the best patterns for the articles they want, and they will obtain them quite as good, or better if it be desired, under a system of open competition. If not, the blame does not rest with the makers, but with the overlookers or parties appointed to receive and test the articles. If the latter be qualified for their duty, and *do* it, the makers must do theirs or be ruined.

It has been more than once suggested to the Russian Government to introduce the system of private enterprise and economy into the manufacture of arms carried on at Tula. Select, it has been said, the best models of the arms to be manufactured; appoint skilful and competent parties from England and elsewhere to see that the articles produced are in all respects equal to the patterns, and offer their production to the lowest bidder. We have been assured that were this system adopted, the cost of the establishment would be reduced a half or more; that the quality of the muskets and other arms would be decidedly improved; and that there would be much greater facilities than at present for introducing new inventions and improvements.

Permanency of manufactures.

All speculations in regard to the future condition of any great department of industry must necessarily be of a very vague and doubtful character. They involve so many considerations which are all liable to perpetual changes, the causes and consequences of which it is impossible to appreciate beforehand, that but little dependence can be placed even on those that are most carefully elaborated. But, were we called upon to express an opinion on the subject, we should say, that provided the public tranquillity and the free disposal and security of property be maintained intact, there is nothing to make it be supposed that the British manufacturing system has arrived at, and much less that it has passed, its zenith.

It has been said by Hume, that "manufactures gradually shift their places, leaving those countries and provinces which they have already enriched, and flying to others, whither they are allured by the cheapness of provisions and labour; till they have enriched those also, and are again banished by the same causes." (*Essay on Money.*)

This is one of the few instances in which Hume has allowed his better judgment to be swayed by popular prejudice. There has not, in truth, been any transfer of the kind to which he refers. The manufactures of the ancient world, which were almost entirely domestic, were not transferred to, but were destroyed by the barbarians; while in modern times the industry of Spain and of the Italian cities of the middle ages fell a sacrifice to the influence of the Inquisition, the establishment of an oppressive system of government, and the discovery of the route to India by the Cape of Good Hope. We have yet to learn that a single instance can be pointed out in the history of the world where, security and other things being about equal, manufactures and trade have left a rich to settle in a poor country. The persecutions of Philip II. and the Duke of Alva, and not the greater poverty of Holland and Zealand, made the manufacturers and merchants of Ghent, Bruges, and Antwerp, seek an asylum in them and in England.

Even in their earliest stages, or when manufactures are principally carried on by the hand, we doubt whether a poor has any advantage over a rich country. Wages may be nominally lower in the former, but the probability is, that they are really dearer. It was said by an excellent judge (Arthur Young) who visited Ireland in 1776-79, that labour in Essex was cheaper at 2s. 6d. than in Tipperary at 5d. a day. Estimated by the work done in a given time, which is the only just standard, labour is uniformly cheaper in rich and industrious than in poor and idle countries. And unless the latter have other and more substantial advantages on their side, their apparently low wages will do them no good and their neighbours no injury.

But if such be the case in the earlier stages of manufactures, the lowness of wages, were it real, and not nominal, has infinitely less influence in determining their locality when they are highly advanced. That is then mainly determined by the command of power, of capital, and of skilled labour. Where these are wanting, or obtainable only in an inferior degree, improved manufactures cannot exist. And as these are enjoyed by this country in the highest perfection, the inference is, that we shall continue, so long as we preserve our security and our freedom, to maintain our manufacturing ascendancy.

Dependence on the United States for supplies of cotton.

The circumstance of the cotton manufacture being dependent for by far the larger portion of the raw material on importations from the United States, has recently been made the subject of a good deal of discussion. It has been said that this state of things is not a little hazardous; that in the event of anything occurring to involve us in hostilities with the States, or that might injuriously affect the growth of cotton in them, our manufacturers might be exposed to the greatest difficulties, and the wellbeing of a large class of our people seriously compromised. It is alleged too, that, independently of the considerations now mentioned, it may be doubted whether America will be able to meet the increasing demand for cotton; and hence it is contended that we should encourage its growth in India, Africa, and elsewhere. But we are not disposed to attach much weight to these considerations. The Americans would suffer as much as we should do, or more, by laying an embargo on the exportation of cotton, which measure, were it really attempted, would inevitably bring about a disruption of the Union. And unless some rash and ill-advised proceedings take place with respect to the slaves, of which there is no prospect, there is every reason to anticipate a very large increase in the produce of cotton in the United States. It is to be observed, too, that should the demand increase for a while faster than the supply, the consequent increase of price would give a new and powerful stimulus to production, which would probably in the end sink prices lower than ever. Neither, we confess, have we much faith in the speculations of those who say that the supplies from India may be largely augmented. Indian cotton is mostly of inferior quality, and the tenure of the land and the character of the natives present formidable obstacles to its extended cultivation. And if little needs be expected from India, far less should be expected from Africa. The prospects of the manufacture will be bad indeed when it comes to depend in any considerable degree on African imports.

On the whole, it would seem that this is a case in which the *laissez faire* and *laissez passer* policy is the most proper that can be followed. The interests of the merchants and manufacturers will lead them to find out the best markets in which to buy the raw material, as well as those in which to sell the finished articles. A rise of a few cents per pound in the price of cotton will do ten times more to stimulate its production in the most suitable localities than all the speeches at all the meetings that will be held on the subject during the next half century. (J. R. M.)

MANUZIO, Aldo Pio (or *Manutius*), the first of those justly celebrated printers who were in Italy what the Stephens afterwards became in France and Geneva, was born in 1447 at Bassiano, in the Roman state. He was educated at Rome, and after completing his course of study, repaired to Ferrara to study Greek under Guarini, a learned professor of that language. In 1482 he quitted Ferrara, then threatened with a siege by the Venetians, and retired to Mirandola, where he was received with distinction by the all-accomplished Pico. Yielding to the entreaties of Alberto Pio, he then went to Carpi, where he was soon joined by Pico, the uncle of the prince. In the course of the year 1488 he repaired to Venice, a city which, from its position, its commerce, and the literary taste of its inhabitants, appeared the best suited for his design. His first object was to make himself advantageously known, and, with this view, he commenced by giving public instructions in Greek and Latin; but in the meantime he was very busily occupied in organizing his printing-house; and at length, in 1494, he published the poem of *Hero and Leander* in Greek and Latin, which was followed by the *Grammar* of Lascaris, that of Theodore Gaza, and the works of Theocritus, Apollonius, and Herodian. But it was the publication of the works of Aristotle which placed Manuzio in the first rank of printers. This edition alone, though less correct than the greater part of those which followed it, would be sufficient to earn for Manuzio the gratitude of posterity, and to justify all the commendations which have been bestowed upon him. Before this time the greater part of books had been printed in the folio or largest size; Manuzio, however, conceived the happy idea of publishing a collection of the Latin classics in a more convenient form, and with this view he had a character cast in imitation (it is said) of the hand-writing of Petrarch, and employed it for the first time in the impression of his Virgil which appeared in 1501. This character, long afterwards known by the name of *Aldine*, and now by that of *Italic*, was designed and cut by Francesco of Bologna. The multiplicity of works which now issued from his presses having rendered it impossible for one individual to superintend the impressions, he had recourse to the assistance of some learned men, his personal friends; and out of this association of persons, united in one common object, he formed the Aldine Academy, whose short duration did not prevent it from attaining great celebrity. It reckoned amongst its members Bembo, Erasmus, Battista Egnazio, and Andrea Navagero, who every year burned, in honour of Catullus, a copy of Martial; the monk Bolzani, the first who wrote in Latin the principles of Greek grammar; Alcyonio, who is accused of having destroyed the only manuscript of Cicero's treatise *De Gloria*, after having transferred its finest passages to one of his own works; the Greek Musurus Demetrius Chalcondylas, who published the first edition of Homer; and Aleandro, afterwards cardinal. In 1506 war obliged Aldo to withdraw from Venice; and during his absence his goods were pillaged and his domains seized. In 1507 he resumed his typographical labours, and subsequently formed a partnership with Andrea Toresano d'Asola, his father-in-law, of which Aldo was constituted the head. He was on the point of publishing a Bible in three languages, when he was in 1515 removed by death, at the age of sixty-eight, leaving his son Paolo to prosecute his father's designs.

The Greek editions which issued from the presses of Aldo are less correct than either the Latin or the Italian editions; but it should be remembered that he had frequently only a single manuscript, incomplete or half effaced, from which to reproduce a work, and that the conservation of many is entirely owing to his laborious patience. The mark of his press, it is well known, is a dolphin coiled round an anchor. Besides the prefaces, and the Greek or Latin dissertations with which he enriched most of his editions, Manuzio was the author of several works, which would of themselves have been sufficient to insure to him a distinguished place amongst the learned men of his age, if he had not been the most celebrated printer it produced. Of these works the most important are,—*Rudimenta Grammatices Linguæ Latinæ*, Venice, 1501, in 4to; *Grammaticæ Institutiones Græcæ*, 1515, in 4to; *Dictionarium Græco-Latinum*, 1497, 1524, in folio; *De Metris Horatianis*, a little work often reprinted during the sixteenth century; *Scripta Tria longe rarissima denuo edita et illustrata*, Bassano, 1806, in 8vo. The Abbé Morelli is the editor of this collection, which contains a poem of Aldus, entitled *Musarum Panegyris*, in two little pieces addressed to the Prince of Carpi. The original edition in 4to, without date, must have appeared before 1489. Manuzio translated from Greek to Latin the *Grammar* of Lascaris, the *Batrachomyomachia*, the *Sentences* of Phocylides, the *Golden Verses* of Pythagoras, and the *Fables* of Æsop and of Gabrias (Babrius). (See *Life of Aldus Manutius the Elder*, by Unger, augmented by Geret, Wittenberg, 1753, in 4to; also his Life by Manni.) (J. B—E.)

Manuzio, *Paolo*, son of the preceding, was born at Venice in 1512, and after the death of his father remained under the care of his maternal uncle, Andrea Toresano. After his uncle's death in 1529, the printing establishment was re-opened in 1533, for the common benefit of the heirs of Aldo and Andrea d'Asola, with Paolo at its head. In imitation of his father, he sought the assistance of learned men, of whose counsels he availed himself; published new editions, particularly of the Latin classics, much more correct than the preceding ones; and enriched them with prefaces, notes, and indexes, the usefulness of which now began to be felt. On the erection of the Venetian Academy in 1558, Paolo Manuzio was appointed professor of eloquence and director of the academical press. On the dissolution of this institution in 1561, a letter from Cardinal Scripandi induced Paolo to repair to Rome, in order to superintend the impression of the works of the Fathers. The first work which proceeded from the new printing establishment was a small treatise of Cardinal Pole, *De Concilio et Reformatione Angliæ*, dated 1562. He died on the 6th April 1574. During the last years of his life his presses had begun to decline, yet Paolo Manuzio, as a printer and editor, was equal to his illustrious father; and his works place him in the rank of the best critics and most polished writers of his age. These were,—*Epistolarum libri xii. Præfationes, &c.*, Venice, 1580, in 8vo; *Lettere Volgari divise in quattro libri*, ibid. 1560, in 8vo; *Degli Elementi e di loro notabili Effetti*, ibid. 1557, in 4to; *Antiquitatum Romanarum liber de Legibus*, ibid. 1557, in folio, with an ample index; *Liber de Senatu Romano*, ibid. 1581, in 4to; *De Comitiis Romanorum*, Bologna, 1585, in folio; *De Civitate Romana*, Rome, 1585, in 4to. These four last treatises have been inserted in the *Thesaurus Antiquitatum Romanarum*, tom. i. and ii. Manuzio translated into Latin the *Philippics* of Demosthenes, Venice, 1549, 1552, in 4to; and he published Commentaries on the Familiar Letters of Cicero, the Letters to Atticus, Brutus, and Quintus; and the Orations, as well as Scholia, on the oratorical and philosophical treatises of the same author.

MANZANARES, a town of New Castile, Spain, capital of the partido of its own name, in the province of Ciudad Real, 98 miles S. of Madrid. Situated in a vast plain 1882 feet above the sea level, it enjoys a serene sky and salubrious climate. The small river Azuel flows near it, and the high road of Andalucia passes through it, forming its main street. The houses are mostly well built, with open courts, covered in summer with an awning. To the S.E. of the town is the ancient castle called De Peñas Borras, with wall and fosse; it was repaired and garrisoned during the war of independence. Besides a grammar school there are six other schools in the town, an hospital, and a recently erected parish church of modern Gothic architecture. The country around is perfectly flat, and quite destitute of wood and water, so that the soil, though fertile, requires careful irrigation; and the want of fuel is supplied with rye-straw, manure, olive, and vine cuttings. The productions of the district are wheat, rye, anise, saffron, potatoes, wine, and oil. A good deal of sheep and horned cattle are reared, as well as mules for plough and carriage. Of manufactures, the town contains four of linen cloth, as many of woollen, besides several of soap and brandy; and lime and tile kilns. It is rather noted for its excellent carriage-makers and workers in iron. A considerable number of the inhabitants are carriers, conveying grain, wine, oil, and oranges, &c., to Madrid, Andalucia, and Valentia. There is a market every Thursday. Pop. (1845) 9060.

MAPES, Walter (or *Map*, which, according to some, is the proper orthography), one of the most noted writers of Latin poetry during the reign of Henry II., was born on the borders of Wales about the middle of the twelfth century. After studying at the university of Paris, Mapes returned to England, where, joining himself to the court, he became a great favourite of Henry II., who esteemed him alike for his extensive learning and courtly manners. This attachment on the part of the king gained for Mapes various ecclesiastical preferments, being made canon of the cathedral churches of Salisbury and St Paul's; and after the successive enjoyment of many other dignities and benefices, was ultimately created Archdeacon of Oxford in 1196. He is supposed to have died about the year 1210. Our information respecting Mapes is chiefly drawn from the *Speculum Ecclesiæ* of his intimate friend Geraldus Cambrensis. (See the Camden Society's edition of *The Latin Poems commonly attributed to Walter Mapes*, edited by Thomas Wright, 4to, London 1841.)

"This genial archdeacon," as Warton calls him (*Hist. of Eng. Poetry*, vol. i., p. cxxvi., 1840), is generally supposed to have been the author of the greater part of the Latin poetry belonging to the latter half of the twelfth century. His vein was witty, festive, and satirical; and he seems to have been endowed with a decided taste for gay, elegant literature. The admirers of middle-age romance recognise him as the author of an important part of the cycle of King Arthur and his knights. The Cistercian monks had the misfortune to encroach on his territory and rights on some occasion, which so keenly roused the resentment of the jovial poet that he kept up a satirical fire against them, both in prose and verse, during the remainder of his life. A considerable number of the poems constantly and unhesitatingly attributed to Mapes, appear in the MSS. under the name of *Golias* or of *Golias Episcopus*. That this was a fanciful appellation given to the imaginary and burlesque representative of the clerical order there can be no doubt. The *Goliardi* are well known, as Mr Wright shows, to have been a riotous and loose class of clerical buffoons, who lived by practising their jests and ribaldry at the tables of the richer ecclesiastics. And while a skilful satirist of the clerical vices would, perhaps, find wider scope for the exercise of his function by assuming the attitude of a *Golias* than by any other mode of attack then open to him, it is nevertheless somewhat singular that Giraldus, who knew Mapes well, was not only led to believe that *Golias* was the real name of the author, but also that, in the very book (*Speculum Ecclesiæ*) in which he praises his friend Mapes so warmly, he takes occasion to censure these satirical verses in no measured terms, and to speak of their author with great severity. But, however this may be explained, there can be no doubt that these verses were ascribed to Mapes at a very early period. His name appears attached to the MS. of certain of these poems in the fourteenth century; and in several copies, belonging to the fifteenth century, of the *Apocalypsis Goliæ*, the most celebrated poem of the class, and still preserved in the Bodleian Library, Mapes is said to be the author; yet Mr Wright expresses strong doubts as to Mapes being the author of any of them. He accordingly, in the volume already referred to, has arranged the "poems bearing the name of Golias," those "attributed to Walter Mapes," and others "of a similar character, but not directly attributed to Walter Mapes," into separate classes. Of the first class, the most celebrated are the *Confessio Goliæ* and *Golias de Conjuge non Ducenda*,—the former containing the famous old drinking song of the "jovial toper," consisting of a number of leonine verses, commencing,—

> "Meum est propositum in taberna mori:
> Vinum sit appositum morienti ori," &c.

Besides gaining the epithet of "The Anacreon of the Twelfth Century," as Lord Lyttelton styles him, Mapes was likewise an industrious prose writer both in the Latin and Anglo-Norman languages. The only remains now known of this species of Mapes' literary labours are,—a treatise entitled *De Nugis Curialium*, edited by Thomas Wright, from the Bodleian MS., for the Camden Society, London, 4to, 1850; and a tract entitled *Valerius ad Rufinam de non ducenda Uxore*. The former is a very curious and interesting production, consisting of severe attacks on the vices of monasteries and courts, monastic stories, fairy legends, graphic notices of Welsh manners, and unceasing tirades against Cistercian monks.

MARACAYBO, Maracaibo, or Nueva Zamora, a town of Venezuela, in South America, capital of the province of the same name, is situated on the W. shore of the strait connecting the Lake of Maracaybo with the sea, 175 miles E.N.E. of Santa Marta, and 320 W. by N. of La Guayra; N. Lat. 10. 41., W. Long. 71. 40. The town is situated on a dry and sandy soil; and the houses are for the most part built of wood, and are thatched with reeds. This gives the town a mean appearance, and renders it very subject to fires. The only public buildings worthy of mention are,—the parish church (an elegant edifice), a chapel, a Franciscan convent, and an hospital. The harbour is deep, but there is a shifting bar at its mouth which prevents large vessels from entering; the anchorage is safe, however, being sheltered by three islands, called San Carlos, Zapara, and Bajo Seco, on each of which stands a castle for its defence. The town carries on a considerable trade, being the principal port for the provinces of Merida and Truxillo, and some of the districts of New Grenada. Cocoa, coffee, honey, sugar, tobacco, ropes, &c., are brought from the interior to Maracaybo, and are thence exported by foreign vessels to other countries. A considerable number of ships are built here. The inhabitants are chiefly employed in nautical pursuits, and are said to form excellent sailors. Many of them also find employment in tending the large herds of cattle which are bred in the neighbourhood. The climate of Maracaybo is oppressively hot; and in the summer season earthquakes are frequent, as well as violent thunder-storms, accompanied with torrents of rain. The province of Maracaybo extends round the lake of the same name, and is low, flat, and unhealthy. Area, 33,082 square miles. It is inhabited chiefly by natives; and had in 1854 a population of 59,311. Pop. of town 14,000.

Maracaybo, *Lake* or *Lagoon of*, the largest sheet of water in South America, being nearly 100 miles in length, and 80 in breadth at the widest part, lies between 9. and 10. 40. N. Lat., 71. and 72. 25. W. Long. This lake is of an oval form, communicating with the sea by means of a narrow channel, 46 miles in length, and varying from 4 to 14 in breadth. It would be navigable for the largest vessels were it not for a shifting bar at the mouth of the strait, over which there is only about 14 feet of water.

The waters, by reason of the numerous rivers which flow into the lake, are fresh and sweet; but towards the northern extremity, especially during the prevalence of N. winds, they are somewhat brackish. The total number of rivers that fall into the lake is said to be 105 perennial streams, and 400 which are dry during some part of the year. Of the former, the principal are,—the Catatumbo, the Zulia, the Escalante, and the Metatan. The shores of the lake are for the most part barren, and during part of the year the whole of its banks are inundated to the distance of 10 or 20 miles. On the N.E. there is a remarkable mine of mineral pitch, which sends out in the night such a brilliant phosphoric light as to serve as a guide to the navigators of the lake, and hence it is called the Lantern of Maracaybo. The lake is not subject to tempests of any great severity; and it abounds in fish and water-fowl. It was first entered by Ojeda and Vespucci in 1499, who gave the name of Venezuela, or Little Venice, to the surrounding country, by reason of the appearance of the Indian villages built on piles driven into the lake, which reminded them of Venice.

The Gulf of Maracaybo, which is also called the Gulf of Venezuela, is an inlet of the Caribbean Sea, having its entrance between Cape San Romano and Point Espada, a distance of 60 miles. It is about 75 miles in length from N. to S., and 150 in breadth. It contains several small islands, and communicates at the S. with the Lake Maracaybo.

MARAGHA, or MARAGA, a town in the province of Azerbijan, and the capital of a district, is situated 50 miles S. by W. of Tabrecz, 10 miles E. of the Lake Urumiah, and 305 miles W.N.W. of Teheran. It stands close to a small river which flows into Lake Urumiah, and here crossed by two bridges built in the eleventh century. The town covers a large extent of ground by reason of the extensive gardens which it contains, and which are extremely beautiful and productive, being watered by canals which intersect the town. Maragha is surrounded by walls, with towers, and contains a large and elegant bazaar, extensive public baths, and the tomb of Holaku, one of the princes of the line of Jenghis Khan. On a mountain in the vicinity are remains of an observatory, built by this monarch for the use of Nazer-a-Deen, a famous eastern astronomer. Pop. about 15,000.

MARANHÃO, MARANHAM, or SAN LUIZ, a town in Brazil, capital of a province of the same name, is situated on a narrow tongue of land on the W. coast of the island of Maranhão, 300 miles E. by S. of Para, Lat 2. 3. S., Long. 43. 50. W. It is built on an uneven surface, and consists of two parts, of which one, called Bairro da Praia Grande, extends along the shore close to the edge of the water; while the other, called Bairro de N. Senhora da Conceiçao, lies further inland. In the former part the houses have generally a very handsome appearance, being for the most part built of sandstone, two storeys high, and furnished with balconies. The streets, however, are generally uneven and irregular. In this part of the town there are several squares, the principal of which is surrounded by the governor's palace, the Jesuit's college, the town-hall, and the prisons. Besides these, the most important public buildings are the bishop's palace and the theatre. Each part of the town has a parish church; besides which, there are several other churches and chapels, and four convents. The back part of the town consists of small houses surrounded by gardens. The educational establishments comprise, a lyceum or college, schools of navigation and commerce, and various other schools. There is also a botanic garden and an English cemetery, laid out with much taste. The harbour of Maranhão is secure, but the entrance is difficult, by reason of a sandbank to the N. of the town, to the E. and W. of which there are deep and good channels. The trade of this place is very considerable. Brandy, wine, oil, flour, linen, hardware, and other European articles, as well as spices, drugs, &c., from the East Indies, are imported; while the exports consist of cotton, rice, caoutchouc, horns, hides, isinglass, sarsaparilla, &c. The whole trade of the north-eastern provinces of Brazil passes through Maranhão, as it is the most considerable seaport on that coast.

The island of Maranhão is of an oblong shape, about twenty miles in length by 12 in breadth. It is difficult of access, on account of the rapidity of the stream by which it is separated from the mainland. This stream is called the Rio de Mosquito, and is shallow, and about 100 yards wide. It terminates in two large bays, the Bahia de San Joze and the Bahia de San Marcos. The island is low and swampy, but fertile and well inhabited; and it contains, besides the town, several small villages.

The province of Maranhão is bounded on the N. by the Atlantic, on the E. by Pianhy, on the S. by Goyaz, and on the W. by Para. It lies between 1. 20. and 10. 50. S. Lat., and 41. 20. and 48. W. Long. The surface gradually slopes from the elevations in the S.W. towards the N.E.; and the principal rivers are the Parnahiba, which forms its eastern boundary, the Mearim, and the Itapicuru, all of which flow in the same direction. The only lake of any importance is the Mata. A great part of the province is covered with primeval forests, and the districts near the coast are fertile and very productive of cotton and rice. Iron, lead, and antimony are found in the province, but have not been mined in any great quantities. The principal towns, besides the capital, are Alcantara and Cachías. The area is 94,900 square miles. Population of the province (1851) 390,000, of the town 36,000, and of the island 40,000.

MARANS, a town of France, department of Charente-Inferieure, near the union of the Sevre-Niortaise and the Vendée, about 13 miles N.E. of La Rochelle. The country in which it stands, having been recovered from the sea, abounds with salt marshes, and is intersected by canals. The town is well built, and has a good bridge over the Sevre, which is navigable here for vessels of 100 tons. A canal has been recently constructed, by means of which ships of 300 tons can come up to the town. The trade is thriving, and consists principally of corn, wine, brandy, hemp, flax, timber, and salt. Pop. 4670.

MARASH, a pashalik of Asiatic Turkey, is bounded on the N. by that of Sivas, E. by Diarbekir, S. by Aleppo, and W. by Karamania, and lies between 36. 3. and 38. 30. N. Lat., and 36. and 38. 40. E. Long.; greatest length 130 miles, greatest breadth 105 miles. This country belongs to the basins of the Euphrates and the Jyhoon, the former of which forms its eastern boundary, while the latter rises near its centre, and flows through it in a S.W. direction. With the exception of the valleys of these rivers the district is entirely mountainous and wooded. It is crossed in the centre from W. to E. by the Taurus ridge, and also by the Antitaurus on the N., and the Durdun-Tagh on the S. The climate is mild, and the country is well adapted for pasturage. The capital is Marash, on the Jyhoon, 60 miles N.E. from the sea. Pop. of pashalik 248,000.

MARAT, JEAN PAUL, was born at Baudry in Neuchatel in 1744. After passing some time in the study of physical and medical science, he resolved to quit his native country and go in search of a wider sphere of activity. We find him accordingly in Edinburgh in 1774, supporting himself by giving lessons in French; and about the same time, his first publication, *The Chains of Slavery*, written in English, made its appearance. This work he afterwards translated into French, and published at Paris in 1792. His second publication, *De l'Homme, ou des Principes et des Lois de l'Influence de l'Ame sur le Corps, et du Corps sur l'Ame*, appeared at Amsterdam in 1775, and had the honour of being subjected to the polemical sarcasm of Voltaire, who undertook to refute it in the *Gazette Litteraire*. Marat still continued to pursue his physical inquiries in a somewhat fitful and irregular manner, and produced his *Recherches Médicales sur l'Electricité* at Paris in 1784. But he was not destined to succeed in this department. His morbid ambition and immoderate vanity scorned to have his upward progress as a scientific reformer checked by the patient observation and laborious experiment requisite to wring from nature her simplest secret. He nevertheless kept writing and publishing his empty paradoxes with surprising activity and boldness, furious at any one who dared to contradict him. But writing and rage failed to supply Marat with the means of subsistence, and we accordingly find him ere long in the streets of Paris, a needy vender of quack medicines. This position he exchanged in 1789 for that of veterinary surgeon at the D'Artois stables. Such had been the antecedents of Jean Paul Marat when the flames of the Revolution broke out in France. He flung himself with wild energy into the heart of this fearful movement, and gained for himself a name of infamy and shame. Marat had tried his hand at political philanthropy in 1787, in his *Plan de Legislation Criminelle;* but his regular political career commenced with the issue of his journal *Le Publiciste Parisien* on the 12th September 1789, shortly after the promulgation of the "rights of man." He afterwards exchanged the title of this paper for that of *L'Ami du Peuple*, a publication which soon acquired a fearful celebrity. This periodical was filled with the most violent denunciations against the court, the ministers, the Assembly, the National Guard, and, in short, against all the constituted authorities of society. These writings of "The People's Friend," read aloud every evening at the squares and public places of Paris, captivated the attention, and excited the passions of the needy and the turbulent. In October 1789 Marat joined the club of the Cordeliers, founded by the celebrated Danton. Having proposed, to the horror of the Assembly, to hang the 800 deputies on 800 trees of the Tuilleries, commencing with Mirabeau, Marat was hunted from one wretched den to another, till the imprisonment of the royal family, and the formation of the new municipality by the republicans on the 10th August 1792; when, emerging from his obscurity, the "People's Friend," arrested and imprisoned the *suspects*, and as a member of the Committee of Public Safety, signed the circular which exhorted the whole of France to imitate Paris, and massacre the so-called aristocrats. On being returned by Paris as a deputy to the National Convention, Marat was denounced in the assembly for having advocated in his paper the guillotining of 270,000 persons as fit objects of public vengeance. He not only admitted the charge, but defended it with great confidence, and with an air of sincerity, as the most effective method for saving the innocent, and for appeasing the people of France. His persuasive tongue not only silenced the angry clamour of the Convention, but even converted their rage into pity, and their shrieks into shouts of applause for "The Friend of the People." Whereupon Marat drew forth a pistol, and placing it to his head, said, if they had passed the accusation decree he would have blown out his brains. The Girondins had long been the objects of Marat's most virulent hatred, and he used every effort for their proscription. This party succeeded in summoning their relentless adversary before the revolutionary tribunal, but he was acquitted, as a matter of course, and carried in triumph by the populace back to the Convention. He soon after assumed the dictatorship, sounded the alarm on the 31st of May 1793, and witnessed the downfall of the Girondins, an event which he only survived till the 13th of July, when the assassin's knife of Charlotte Corday, a young Norman lady, who found access to his squalid apartment, put an end to his atrocities, and "did France a great service." (See Corday.) His death, however, was only hastened by a few days, for he was already, says a historian, "ill of revolution fever,—of what other malady this history had rather not name." He was living in a state of want and wretchedness, for it had never been his aim to amass wealth. He on one occasion sold his bed to enable him to publish his journal; and even when he had reached the summit of power, he continued to reside in a mean apartment with the wife of his printer, who is said to have loved him. After his death he was regarded as a martyr of liberty, and almost adored by the Jacobins. He had Pantheon honours and a public funeral decreed him. The dust of Mirabeau had to make way for him, and his heart was enshrined in a golden urn.

MARATHON, a city of Greece, on the E. coast of Attica, situated in a plain of the same name, is said to have been founded by Xuthus, who married the daughter of Erechtheus, and to have derived its name from the hero Marathon. Originally it constituted, along with three other cities, the district of Tetrapolis; but when that district was incorporated by Theseus into the state of Attica, Marathon, as the most important of the four cities, gave its name to the neighbourhood. Here Eurystheus was defeated and slain by Iolaüs the Heracleid; and here Theseus slew the furious bull, the pest of the plain (Str. viii.; Ovid. *Met.* vii. 433). But Marathon is chiefly famous as the battle-field on which the Athenians, in 490 B.C., defeated the Persians, and vindicated the independence of Greece (Herodot. vi. 102.) A monument to the memory of Miltiades, and the two tumuli that covered the slain of the Athenians and Platæans respectively, stood on the field in the time of Pausanias (i. 32). The former of the tumuli, about 600 feet in circumference and 30 in height, is still seen standing in the centre of the plain, about a mile and a half from the shore. (For a minute account of the plain of Marathon, see Colonel Leake's *Demi of Attica*, vol. ii.)

MARATTA, Carlo, the last celebrated painter of the Roman school, was born at Camorano, near Ancona, in 1625. He went a poor boy to Rome when only eleven years of age; and at twelve recommended himself so effectually to Andrea Sacchi by his drawings after Raffaelle in the Vatican, that he took him into his school, where he continued twenty-five years, that is, until his master's death. His graceful, dignified, and beautiful ideas occasioned his being generally employed in painting Madonnas and female saints, and procured for him the name of *Carlo delle Madonne.* From the finest statues and pictures he made himself master of the most perfect forms and the finest positions of heads, which he sketched with equal ease and grace. He has produced a noble variety of draperies, artfully managed and richly ornamented. He was inimitable in adorning the heads, in the disposal of the hair, and the elegance of his hands and feet, which are little inferior to those of Raffaelle himself. In his younger days he etched a few prints with spirit and correctness, and had the famous engraver Jacob Frey for his pupil. It would be tedious to recount the celebrated paintings executed by this great artist. Besides the famous picture of Daphne, painted for Louis XIV., he made several admirable portraits of popes, cardinals, and other persons of distinction, from whom he received the highest testimonies of esteem, as he likewise did from almost all the monarchs and princes of Europe. He died at Rome in 1713, in the eighty-eighth year of his age. See Lanzi.

MARAZION, or Market Jew, a market-town of England, county of Cornwall, on the slope of a hill on the coast of Mounts Bay, 18 miles W.S.W. of Falmouth, and 280 W. by S. of London. The town has a parish church and places of worship for Wesleyan Methodists and Baptists, a national school, an endowed school, and several charitable institutions. The trade is principally in iron, timber, and coals, which are imported for the use of the mines; and the inhabitants are chiefly employed in the tin and copper mines in the neighbourhood. Market-day Saturday. Opposite the town is St Michael's Mount, a small rocky island about a mile in circumference, and accessible at low water by means of a narrow causeway. In the middle ages it was much resorted to by pilgrims, and had a priory of Benedictine monks. The climate of Marazion is very mild, but is subject to heavy rains. Pop. (1851) 1379.

MARBELLA, a town of Spain, province of Malaga, on the coast of the Mediterranean, 30 miles W.S.W. from the town of Malaga. Few towns on the coast of Spain enjoy a more delightful air or a more charming prospect: from the summit of the Sierra Blanca, behind the town, is seen the mountainous coast of Africa, and to the right rises the rock of Gibraltar; farther on, the town of Estepona, half concealed by wooded hills. The streets are regular, broad, and clean. In the centre stands an ancient Moorish fortress, commonly called the Castillo, within whose inclosure is the cemetery and several religious edifices. There are two public schools and an hospital; the parish church is a large, handsome edifice of modern construction. The schools occupy the ex-convent of San Juan de Dios. On the coast near Marbella are the ruins of the Castle of St Luis, destroyed by the French in 1812. Many of the inhabitants are engaged in fishing; and the sardines taken on this coast are of excellent quality. Marbella rose into importance some years ago upon the discovery of iron in the Sierra Blanca; it is smelted here, and sent on to Malaga to be refined. The principal iron-works are the property of the Heredias of Malaga, and give support to upwards of 130 families, independently of those engaged in the mines. The commerce consists in the importation of oil, wheat, and barley, and in the exportation of sardines and other fish, figs, raisins, and wine, which, though in no great quantity, is of excellent quality. Pop. (1845) 5105. Marbella is the *Sarduba* of Pliny and Pomp. Mela, which, according to Bochart, is its Phœnician equivalent, meaning "City of Salt."

MARBLEHEAD, a seaport-town in the county of Essex, state of Massachusetts, North America, is pleasantly situated on a rocky promontory of the same name, 18 miles N.E. of Boston. The harbour is excellent, being accessible at all times to the largest vessels, and protected from the violence of storms by a breakwater, built in 1845. The inhabitants are chiefly employed in cod-fishing and curing. About 60 boats are employed in the former of these occupations, and about 60,000 cwt. are taken annually, in the curing of which more than 60,000 bushels of salt are used. The principal articles of manufacture are boots, shoes, and cordage. The number of foreign vessels which entered Marblehead harbour during the year ending 30th June 1852 was 168, with a tonnage of 12,129; and the number cleared out was 162, tonnage 11,675. Pop. 6167.

MARBURG, or Mahrburg, a town in Styria, capital of a circle of the same name, is situated on the left bank of the Drave, 36 miles S.S.E. of Gratz. The town is surrounded by walls, and has several suburbs. The principal buildings are,—a castle, a church adorned with several fine pictures, a theatre, gymnasium, military school, and hospital. It has a considerable trade in leather, iron, corn, wine, fruits, &c.; and several annual fairs are held here. The neighbourhood of the town is extremely picturesque, and abounds in vineyards. Marburg is the second town in Styria. Pop. about 5000.

Marburg, a town in Hesse-Cassel, capital of the circle of Upper Hesse, is pleasantly situated on the right bank of the Lahn, 48 miles S.W. of Cassel, and 60 miles N. by E. from Frankfort. The town is not well built, and lies in the form of a semicircle on the slopes of a hill, on which stands a castle formerly the residence of the landgraves of Hesse. Marburg is partly surrounded by walls, and has five gates. The streets are narrow, and in many cases so steep as to be ascended by flights of stairs. The university of Marburg was the first Protestant one established in Germany, being founded by Philip the Generous in 1527. It is attended by about 270 students, has 62 professors and teachers, and a library of about 100,000 volumes. The principal of the other buildings are,—the castle, which in 1529 was the scene of a religious conference between Luther, Melancthon, Zwingle, and others of the Reformers, regarding transubstantiation; and the church of St Elizabeth, a beautiful specimen of the Gothic style, begun in 1235, and completed in 1283, containing the monument and silver coffin of St Elizabeth. Besides this, Marburg possesses two Lutheran and one Calvinist church, a gymnasium, a school of industry, a normal school, a school of surgery, a botanic garden, an hospital, two infirmaries, &c. There are also manufactories of stockings, hats, tobacco, tobacco-pipes, &c. Marburg is the seat of the principal law courts for Upper Hesse. On the other side of the Lahn stands the suburb of Weidenhausen. Pop. of the town, with the suburb of Weidenhausen which stands on the opposite side of the Lahn, 7954.

MARCANTONIO, also known by his family name *Raimondi*, an eminent Italian engraver, is supposed to have been born in Bologna about 1487. After studying painting in that city under Francesco Francia, he repaired to Venice to prosecute his art still further. Seeing, however, exposed to sale some woodcuts of the eminent Flemish artist Albert Dürer, he expended all his money in buying them, and began to imitate them on copper. So faithfully copied was one of these imitations, representing the Life and Passion of our Saviour, that when it had been marked by the initials of Dürer, it is said by Vasari to have been sold throughout all Italy for the work of that eminent engraver. When Albert Dürer, however, heard of this illegal use of his name, he hastened to Venice, and induced the senate to issue a command prohibiting Marcantonio from again employing his signature. Removing soon afterwards to Rome, Marcantonio introduced himself to the notice of Raffaello da Urbino, by a copperplate which he executed of the "Lucretia" of that master. Raffaello accordingly employed him in engraving many of his other designs, including the "Judgment of Paris," the "Slaughter of the Innocents," the "Rape of Helen," and the "Death of Santa Felicita." With so masterly and delicate a hand did Marcantonio execute this undertaking, that his fame spread rapidly, and pupils flocked to him from all quarters. His engravings of the heads of the Cæsars, after ancient medals, wrung a commendation even from the offended Albert Dürer. After the death of Raffaello in 1520, he was employed by Giulio Romano to engrave several of his designs. Among these were twenty plates of figures so grossly indecent, that Pope Clement VII., in a virtuous indignation, threw Marcantonio into prison. There he might have paid an extreme penalty for his crime, had not Cardinal de' Medici and Baccio Bandinelli effectually sued for his release. He then returned to the practice of his art; and by his exquisite engraving of the picture of Baccio Bandinelli, representing the martyrdom of San Lorenzo, he so delighted the pope, that he was forgiven for his former offence and received into favour. More profitable patronage might have been extended, had not the sack and pillage of Rome by the Spaniards followed in 1527. Marcantonio barely escaping with his life, returned a beggar to his native city. He died there not many years afterwards.

Besides being a master in his art, Marcantonio earned the distinction of giving the first stimulus to engraving in Italy. A very full catalogue of his works is given in Heinecken's *Dictionnaire des Artistes*. About 500 of them may be seen in the Print Room of the British Museum. Many of his engravings are anonymous, and some are marked with M.A. or M.A.F. (Vasari is the best authority for his biography. See also Lanzi's *Stor. Pittor.* i.)

MARCELLIN, or Marcelin, *St*, a town of France, capital of a cognominal arrondissement in the department of Isère, is situated at the foot of a beautiful slope near the right bank of the Isère, 21 miles W.S.W. of Grenoble. It is surrounded by walls, and is generally well built. Its chief manufacture is earthenware, and it has some trade in silk and wines. Pop. (1851) 3344.

MARCELLUS, M. CLAUDIUS, the conqueror of Syracuse, was probably born at some period before 268 B.C. He is said by Plutarch to have early shown a valorous spirit and a fondness for single combat. The first public office he is recorded to have filled was that of curule ædile. In 222 B.C. he became consul for the first time. The war with the Cisalpine Gauls was then drawing to a close, and the Insubres had sued ineffectually for peace. Marcellus joined the army without delay, and laid siege to Acerræ (*Gerrha*), on the banks of the Po. When the Gauls attempted to make a diversion by attacking Clastidium, he left his colleague before Acerræ, and having reached them by forced marches, defeated them, and slew their general, or king, Viridomarus, with his own hand. This was the third time that a Roman general had presented the *spolia opima* to Jupiter Feretrius. Marcellus obtained the honours of a triumph, which is said to have been one of the most magnificent ever witnessed in Rome. At the commencement of the second Punic war (B.C. 218), Marcellus was appointed as prætor to the command of the troops in Sicily; but he was recalled after the defeat at Cannæ (2d August B.C. 216), and sent to Apulia to collect the remains of the shattered Roman army. This he effected with much prudence; and the severe check which Hannibal received from him before Nola, tended greatly to reanimate the drooping spirits of his countrymen. Hannibal used to say, that he feared Fabius as his schoolmaster, and Marcellus as his enemy. Marcellus was again named consul, B.C. 215; but owing to the unfavourable prognostications of the augurs he immediately abdicated, and proceeded to Nola as proconsul. In the following year he was raised a third time to the consulship, and proceeded to the command of the war in Sicily. There he began to storm Syracuse by sea and land; but his powerful engines were baffled at every point by the more powerful contrivances of Archimedes; and not till after a blockade, of three years was the city taken. In the lawless pillaging that ensued, Marcellus attempted in vain to save the life of Archimedes. That philosopher was slain when absorbed in his mathematical studies. During the blockade, Marcellus, at the head of part of his army, had been waging a desultory warfare with the Carthaginians in Sicily; yet, with the exception of a few towns, that island remained unsubdued. Accordingly, on his return to Rome, Marcellus was only honoured with an ovation or lesser triumph. He brought from Syracuse many beautiful statues and paintings, and was the first who taught the Romans to appreciate the exquisite works of Greece, hitherto unknown to them. He was named for the fourth time consul, B.C. 210, and the command of the war in Sicily fell to him by lot; but he exchanged it for Italy with his colleague Lævinus. Marcellus recovered several cities of the Samnites from Hannibal, who carefully shunned any regular battle with his opponent. In the following year he retained the command of his army as proconsul. He was appointed consul the fifth time, B.C. 208, when he fell into an ambush which had been laid for him by Hannibal, and was killed. Thus fell Marcellus, who was called the *sword* of Rome, in contrast with Fabius, who was entitled its *buckler*. Plutarch and Livy, the chief authorities for the life of Marcellus, represent him as having gained many victories over Hannibal. Yet Polybius (xv. 2) denies that he ever defeated the great Carthaginian at all, a testimony that certainly countenances the opinion that Marcellus is generally overrated. In fact, he seems to have been brave, daring, and hot-headed; with much of the obstinate harshness of an illiterate soldier, and with little of the far-seeing prudence of a great general.

MARCELLUS, *M. Claudius*, of the same family as the conqueror of Syracuse, first appears in history as curule ædile, along with P. Clodius, in 56 B.C. He was named consul (B.C. 51), along with Sulpicius Rufus; and he proposed that Cæsar should be deprived of the command of the armies of Gaul; but this advice was not followed. (Cic. *Att.* vii. 1.) The civil war broke out (B.C. 49), and Marcellus joined the party of Pompey; but on the death of the latter (B.C. 48), he ceased to take part in the political affairs of his country, and retired to Mitylene, that he might not witness the overthrow of the republic. Here he was found by Brutus as he was returning from Asia. (Senec. *ad Helv.* c. 9.) His friends at Rome, however, were anxious that he should return, and they did not find it difficult to prevail on Cæsar to forget the part he had taken against him. His pardon, indeed, was more readily granted by Cæsar than accepted by Marcellus. If we may judge from the letters addressed to him by Cicero, and now known as the seventh, eighth, ninth, and tenth of the fourth book of *Epistolæ ad Familiares*, Marcellus was unwilling to leave his retreat at Mitylene. He, however, yielded, and had reached Athens on his way homewards, when one of his companions in exile, P. Magius Chilo, actuated by private resentment, murdered him, B.C. 46. His old colleague, Sulpicius, happened to be at Athens at this time, and superintended the celebration of his funeral rites. (Cic. *ad Div.* iv. 12.) Marcellus is the subject of the eloquent speech *Pro M. Marcello*, often erroneously ascribed to Cicero.

MARCELLUS, *M. Claudius*, son of C. Marcellus and of Octavia, the sister of Augustus, was born about 43 B.C. He was educated by his mother with the utmost care, and gave early indications of all those qualities that unite in forming a great and good character. In 39 B.C. he was betrothed to Pompeia, the daughter of Sextus Pompey, then a girl of six years of age. (Dion Cass. xlviii. 38.) Released, however, from this engagement by the death of Pompey in 35 B.C., he married Julia, the daughter of Augustus, in 25 B.C., and at the same time became the adopted son of his father-in-law. (Dion Cass. liii. 27; Suet. Aug. 63.) Marcellus was also admitted into the senate, and received the privilege of sueing for the consulship ten years before the legal period. He became curule ædile in 23 B.C., but he died in the autumn of the same year, owing, it is said, to the imprudent use of a cold bath, prescribed by Antonius Musa, the celebrated physician of Augustus. (Dion Cass. liii. 30.) Fond of study, gentle in his disposition, and temperate in his habits, Marcellus was the idol of his countrymen, and his death was mourned as a public calamity. As it had been generally understood that Augustus intended him for his successor, a rumour became current that the Empress Livia had poisoned him, to secure the succession to her own son, Tiberius. The death of Marcellus was the cause of the most intense sorrow to his mother, Octavia, and to Augustus. The latter interred him, with the greatest pomp, in the Julian mausoleum, pronounced his funeral oration, and afterwards dedicated to his memory the magnificent theatre known as the *Theatrum Marcelli.* (Tacit. *Ann.* iii. 64.) But Marcellus is now best remembered by the touching description of him in the Æneid, which is said to have affected his mother even to fainting:—

> Heu ! miserande puer, si quid fata aspera rumpas,
> Tu Marcellus eris.

MARCH, the third month of our modern year, containing thirty-one days. As in the Roman year, so in the English ecclesiastical calendar, used till 1752, this was the first month, and the legal year commenced on the 25th of

March. The Romans called this month *Martius*, from the god Mars, the reputed father of their nation; and it received the name *Hlyd Monath, i.e.*, loud or stormy month, from the Anglo-Saxons. There is an old saying, common to both England and Scotland, which represents March as borrowing three days from April; which are thence called the *Borrowing* or the *Borrowed days.* In the "Complaynt of Scotland," we find "the borial blastis of the *thre borouing dais of Marche* hed chaisset the fragrant flureise of evyrie frut-tree far athourt the feildis." And these *borouing dais* are described in the glossary as "the three last days of March" to which the following popular rhyme refers:—

> "March borrowit from Averill
> Three days, and they were ill;"

and then there is another rhyme, which graphically characterizes those three "ill" days in detail,—

> "The first, it sall be wind and weet,
> The next, it sall be snaw and sleet;
> The third, it sall be sic a freeze,
> Sall gar the birds stick to the trees."

Dr Jamieson, in his *Etymological Dictionary of the Scottish Language*, says, "These days being generally stormy, our forefathers have endeavoured to account for this circumstance, by pretending that March *borrowed* them from April, that he might extend his power so much longer. . . . . . Those who are much addicted to superstition will neither borrow nor lend on any of these days."

MARCH, a market-town in the Isle of Ely, Cambridgeshire, England, is situated on both sides of the Old Nene, 13 miles N.W. of Ely, and 32 miles N. by W. of Cambridge. The town consists of two main but narrow streets, and the houses are low and ill-built. The church is a fine old building of the fourteenth century, and there are also Baptist and Independent places of worship, and national schools. The River Nene, which is here crossed by a bridge, is navigable to the town, and affords it the means of carrying on a considerable trade in corn, hemp, flax, coal, timber, &c. Market-day, Friday. Pop. (1851) 4171.

March, *Morawa*, or *Morava*, a river in the Austrian dominions, giving its name to Moravia, rises on the confines of Bohemia and Glatz. It flows in a southerly direction through Moravia, and receives many considerable streams, such as the Hanna, Taya, Zaya, and Rust, on the right, and the Beczwa, Miava, and Bodawa, on the left. It then forms the boundary between Hungary and Austria, and falls into the Danube above Presburg. The principal towns on its banks are,—Olmutz, Kremsir, and Hradisch. It is navigable for about 50 miles to Goding on the boundary of Moravia. Total length, 180 miles.

MARCHAND, Prosper, a learned bibliographer, born in 1675, at Guise, in Picardy, studied at Paris with much success, and having from his infancy been passionately devoted to books, he was admitted in 1698 into the corporation of booksellers. An eager collector of literary anecdotes, he transmitted them to Jacques Bernard, who then conducted in Holland the *Nouvelles de la République des Letters.* In 1711 Marchand passed into Holland, that he might be more free to profess the Reformed religion, which he had embraced. He established himself at Amsterdam, and there continued for some time the business of bookselling, but ultimately abandoned it altogether, in order to devote himself exclusively to study. He died on the 14th of June 1756, and left his rich library to the University of Leyden. In addition to his extensive annotations, &c., Marchand's principal works are,—*Histoire de l'Origine et des premiers Progrès de l'Imprimerie*, Hague, 1740, in 4to; *Dictionnaire Historique*, or Critical and Literary Memoirs of different distinguished persons, particularly in the republic of letters, Hague, 1758, 1759, two volumes folio.

MARCHE, an old province of Central France, bounded on the N. by Berri, N.E. by Bourbonnais, E. by Auvergne, S. by Limousin, S.W. by Guyenne, and W. by Angoumois and Poitou. It now forms the greater part of the department of Creuse, and parts of those of Haute-Vienne, Charente, and Indre.

MARCHENA, a town of Spain, in the province of Seville, situated in a sandy valley and on two small hills, 30 miles E.S.E. of Seville, was formerly surrounded with walls and towers, of which some remains are still to be seen. The town contains about 1584 houses, generally of two storeys, and the streets are narrow and tortuous. The most remarkable buildings are the palace of the dukes of Arcos, formerly lords of the town, within the inclosure of which is the ancient church of St Mary de la Mota, the tower of which is of some architectural merit; and the church of St John, the present structure dating from 1490. At the eastern extremity of the town is a sulphureous spring resorted to for the cure of cutaneous diseases. The soil of the surrounding district is partly clayey and partly sandy; a seventh part of it is wood or pasture; the rest is under cultivation. The productions are wheat, barley, beans, peas, vetches, olives, oil, grapes, and wine. The wheat, barley, oil, and wine are exported to Seville, some oil even to Malaga. Horned cattle and sheep are reared, as also mules and horses; the River Corbones furnishes fish. Ordinary linen and coarse woollens are manufactured. There are also potteries of common earthenware. A cattle-market is held the first three days of September. Pop. (1845) 11,620.

MARCION, the founder of the sect of the *Marcionites*, is generally held to have been the son of the Bishop of Sinope, and to have been born in that city about the beginning of the second century. He is said by Tertullian to have been a shipmaster, and Rhodon calls him a seaman. Possessed of an earnest and independent mind, he probably arrived at a belief in Christianity without any human aid, an opinion that is supported by the reference which he makes to "the first glow of his faith." After thus receiving the Scriptures, Marcion proceeded in the same bold yet sincere spirit to interpret them. Startled by the seeming dissimilarity between God as manifested in Christ, and God as revealed in nature, he jumped at once to the conclusion that they are two distinct and irreconcileable beings, the one good and loving, the other inexorable and cruel. This doctrine once adopted, he immediately reduced to practice, by neglecting the body as the work of the latter, and by stringently obeying the gospel as the sole emanation from the former, by becoming a severe ascetic, and by presenting a great part of his estate to the church. As he proceeded in his speculations he saw the same contrariety between the Jehovah of the Old Testament, whose characteristic appeared to be jealousy, and the God of the New Testament, whose essence is love. A like antagonism he seemed to discover between the Messiah of the Jews, the destined heir of a large worldly kingdom, and Jesus, the poverty-stricken man of sorrow. Thus he was gradually led to reject the Old Testament as directly contradictory to the New, and as intended for the Jews only, and not for the whole of mankind. This heresy was very probably the cause of his excommunication from the church at Sinope. Marcion then repaired to Rome, in the hope that his new doctrine would awaken some sympathy in the church of that city, but there also he was rejected as a heretic. Discountenanced so severely by all professing Christians, he now began to consider himself the sole representative of primitive Christianity. Accordingly, he set himself to arrange his opinions into a system that might be received into the minds of men, and in this task he was assisted by a Gnostic teacher named Cerdo. He displayed remarkable zeal in making converts to his opinions, and with apostolic spirit he journeyed frequently abroad, glorying to

Marcion.

endure privation, malice, and contempt, and loving to address his proselytes as "fellow-sufferers of hate and hardship." Yet Marcion still cherished a sympathy and respect for many of his former friends, a circumstance that may have partly originated the prevalent opinion that he desired in his latter years to be re-admitted into the church. He is said by Irenæus to have met the venerable Polycarp at Rome, and to have asked him if he remembered him. "Yes," was the reply, "I remember thee, the first-born of Satan." The date of Marcion's death is unknown.

The following is an outline of the creed of the Marcionites in its later and more developed form. They assumed that there were three original principles:—(1.) The good, perfect, and holy God; (2.) the evil Matter; and, (3.) the Demiurge, a being of finite power and imperfect goodness, who is sometimes, but improperly, styled God. Between the two last principles there is a natural and never-ending conflict for the mastery. It began by the Demiurge laying hold upon a part of matter and forming out of it the world and all its inhabitants. Into the human creature—his masterpiece—he infused a soul, moulded out of his own essence, after his own image, and bounded his conduct by a law which he might not transgress on pain of punishment. But man, thus formed of two antagonistic elements, was tossed to and fro by their conflicting influences, until he was driven beyond the boundary which his Maker had set up, and was consigned to the dominion of matter, and the evil which it necessarily entails. The Demiurge then selected the Jews to be his representatives on the earth, gave them a ceremonial and a moral law, promised happiness as a reward of their obedience, and threatened perdition as a punishment of their disobedience. He also foretold a Messiah, who should conduct the Jews to the height of earthly felicity, and spurn the heathen into the depth of misery and ruin. At this crisis the good God, who had hitherto sat remote in a holy inactivity, interfered to thwart the unjust designs of the Demiurge. Deeming it cruel that men should be punished for an imperfection that is innate, and therefore insurmountable, he sent into the world his son, Christ (a man in semblance, but not in reality), with an offer of divine life and blessedness to all who should merely trust in him. This message of love, so directly opposed to the message of justice that had hitherto been proclaimed, incited the Demiurge to crucify the Divine Messenger, and to attempt to bind him in hell. To this apparent defeat the Son of God submitted, for no other purpose than to free the souls of the dead who were held under punishment by the Demiurge. Accordingly, he clad himself in his native omnipotence, released all the Gentiles in the place of torment, ascended in triumph along with them to his Father's heaven, and thus crushed and confounded the tyranny of his enemy. Thither all who believe in his name will follow, but all who reject his gospel will be left to the judgment of the Demiurge.

From this system of doctrine there necessarily arose a system of morals different in many respects from those of other Gnostics. The Marcionites held that, in purifying the heart and regulating the conduct, the *law* was powerless, but the *gospel* effective. They gloried in suffering martyrdom, and they refused to baptise all those who would not resist the power of matter by leading a life of asceticism, and refraining from marriage.

Marcion considered St Paul the only genuine teacher of Christianity. Accordingly, he rejected all the books of the New Testament except the works of that apostle. He acknowledged also a pretended original gospel, which was nothing else than a mutilated copy of St Luke. Marcion wrote a work entitled *Antithesis*, in which he quoted the apparent contradictions between the Old and the New Testament. (See Neander's *Church History*, vol. ii., p. 129. Bohn, 1850.)

Marcomanni || Mardin.

MARCOMANNI, a powerful confederacy of ancient Germans, who were resident, as their name imports, on the borders. They are first mentioned in history by Cæsar, and seem at that time to have dwelt upon the banks of the Rhine. From Tacitus, Paterculus, and Strabo, we learn that they soon afterwards moved westward, under their king Maroboduus, drove the Boii out of Bohemia, and settled in that country. After organizing a government, Maroboduus formed a league with the neighbouring tribes, for the purpose of defending Germany against the Romans. He was thus enabled to muster 70,000 disciplined soldiers, and to conclude an honourable treaty with the Emperor Tiberius, A.D. 6. Yet he was defeated by the Cherusci and their allies A.D. 17; and in two years afterwards he was expelled from his throne by the Goth Catualda, and forced to seek a refuge in Italy. The same fate soon afterwards befell his dethroner and successor, and the Marcomanni once more came under the sway of native kings. After this they gradually extended their dominions, until they had reached the Danube, and had provoked the jealousy of the Romans in the time of Domitian. Then began those hostilities between the Romans and the Marcomanni, which, after being checked by Trajan and Hadrian, and resumed with fresh animosity in the reign of M. Aurelius, issued, in 166, in the protracted struggle of the Marcomannic war, and were finally quelled by the peace of Commodus, in 180. Favoured, however, by the feeble rule of this last emperor, the Marcomanni continued their predatory inroads into the Roman provinces of Noricum and Rhætia, and ventured sometimes as far as the defiles of the Alps. In 270, in the reign of Aurelian, they pushed forward into Italy, and penetrated even to Ancona, spreading consternation around them. After this period they disappear gradually from history, and are mentioned for the last time among the hordes of Attila.

MARCOUF, or MARCOU, ST, two small islets lying in the English Channel, off the coast of Manche in France, about 4 miles from the mainland, and 12 miles N.E. of Carentan. They are mere barren rocks, but in a military point of view are of considerable importance as defences for the roadsteads of Havre and Cherbourg. The navigation is here very dangerous, and they cannot be approached without a pilot. They were taken by the British in 1795, but restored to France at the Peace of Amiens.

MARCUS, THE HERESIARCH, a Gnostic philosopher, lived in the second century. From his frequently employing forms from the Aramæan liturgy, Neander infers that he was born in Palestine. Yet Jerome holds that he was an Egyptian, a supposition confirmed in a great measure by the fact that he was a disciple of Valentine. According to Irenæus and other fathers, he was systematically addicted to licentiousness. Concerning his life nothing further is known. "Marcus set forth his system in a poem, in which he introduced the divine Æons discoursing in liturgical forms, and with gorgeous symbols of worship. After the fashion of the Jewish Cabala, he discovered special mysteries in the numbers and positions of letters. The idea of a λόγος τοῦ ὄντος, of a word manifesting the hidden divine essence in the creation, was spread out by him into the most subtle details; the entire creation being, in his view, a continuous *utterance* of the ineffable." (Neander's *Church Hist.*, sect. iv.) The followers of Marcus were called *Marcosians.*

MARDIN, a town of Asiatic Turkey, in the pashalik of Diarbekir, on a bold limestone crag of Mount Masius, about 2300 feet above the sea, 57 miles S.E. of Diarbekir, and 335 N.W. of Baghdad. The summit of the rock is occupied by the castle, and the town is built on the southern and eastern sides. The streets consist of terraces, running along the hill, and are joined to each other by flights of steps. The houses are built of stone, and are in general small, with flat roofs. The town possesses eight mosques, with some bazaars and public baths. The castle is now in ruins, but commands a magnificent view over a large extent of rich and well cultivated land. Linen and cotton fabrics are manufactured here, and a considerable trade is carried on in these and other articles. The population is estimated at about 20,000, two-thirds of whom are Mohammedans, and the remainder Christians with a few Jews.

MAREE, Loch, a lake in the parish of Gairloch, Ross-shire, Scotland, near the W. coast, is situated in a mountainous and little frequented district. It is about 20 miles in length, and has an average breadth of 1½ miles. It is fed by many mountain streams, and discharges its waters by the Ewe into an arm of the sea called Loch Ewe, which lies to the N.W. The scenery of the loch is of the wildest and most sublime description, the mountain summits which surround it rising in some places to the height of 3000 feet
5000 above the sea. Near the centre of the loch there is a group of islands, about twenty-seven in number. The largest of these is called Ealan Sovin, or St Swithin's Isle, and has an area of about thirty acres.

MAREMMA, La, or Maremme, the name given by the Italians to the marshy regions which stretch along the coast of the Mediterranean, but more particularly applied to those in Tuscany and the States of the Church. This tract of country is extremely unhealthy, especially from midsummer to the autumnal equinox, when it is exceedingly dangerous, and often fatal, to spend a single night in the Maremma; so that the country which was anciently the seat of the most flourishing Etruscan cities, is now almost entirely deserted. The Maremma is divided into several basins by mountain ridges which stretch from the Apennines to the coast. The first basin extends from Lucca to the ridge of Montenero, S. of Leghorn, and stretches about 10 or 12 miles inland. The second basin is smaller in extent than the first, and extends to a few miles S. of the Cecina, where the mountains again approach the sea. This part is called the basin of Cecina. The third basin stretches into the Papal territory, and is bounded on the S. by Mount Cimino, which divides it from the basin of the Tiber. The fourth basin, that of the Lower Tiber, extends as far as the Alban Mount, which separates it from the fifth, that of the Pontine Marshes. Similar plains stretch into the kingdom of Naples, but they are known by the name of Paduli. The Tuscan government have made considerable improvements in the northern part of the Maremma by means of drains and embankments, and parts of the ground have been brought into cultivation.

MARENGO, a village in the Sardinian States, Italy, is situated in a large plain near the Bormida, 3 miles E. by S. of Alessandria, of which it is sometimes regarded as a suburb. It is remarkable for the victory gained here, 14th June 1800, by the French under Napoleon, over the Austrians under Melas, by which the former became masters of all the north of Italy.

MARENNES, a town of France, capital of a cognominal arrondissement, in the department of Charente-Inferieure, is situated near the mouth of the Seudre, about a mile from the Bay of Biscay, and 24 miles S. of La Rochelle. Marennes is a well-built and thriving commercial town, with tribunals of primary instance and of commerce. It is surrounded by salt marshes, which render it very unhealthy, but constitute a great source of profit to the town from the salt that is got from them. The principal articles of commerce are salt, oysters, brandy, and agricultural produce. Pop. (1851) 4534.

MARGARET, Queen of Denmark, Norway, and Sweden, called the *Semiramis of the North*, was the daughter of Waldemar III., King of Denmark, was born at Copenhagen in 1353, was married to Haquin, King of Norway, in 1363, succeeded her husband on the throne of Norway in 1380, and her son on the throne of Denmark in 1387, wrested the crown of Sweden from Albert in 1397, and died in 1412. See Denmark, Norway, and Sweden.

Margaret *of Anjou*, daughter of René, titular king of Sicily, was born in 1425, was married to Henry VI. of England in 1443, and died in 1482. See England.

Margaret *of France*, daughter of the French king Henri II., was born in 1552, was married in 1572 to the Prince of Béarn, afterwards Henri IV. of France, and died in 1615. See France.

MARGARITA, an island in the Caribbean Sea, lies off the coast of Venezuela, of which republic it forms a province, 30 miles N. of Cumana; Lat. 11. 30. N., Long. 64. W. It is about 45 miles in length, and varies in breadth from 5 to 20 miles. Area 441 square miles. It is separated from the mainland by a channel 20 miles in breadth, which has to be passed through by all vessels approaching from the E. the ports of Venezuela. The island is composed of two parts, united by a low and narrow isthmus, so that from a distance it presents the appearance of two distinct islands. At the isthmus the land is not more than 10 or 12 feet above the level of the sea, but near the western extremity a lofty mountain, called Maranao, rises to the height of 3000 feet. Near the sea the soil is dry and unproductive, and the coasts are rugged and bold, indented, however, with three harbours, Pampatar on the S.E., Pueblo-de-la-Mar on the S., and Pueblo-del-Norte on the N. In the interior, the soil, though sandy, is fertile, and produces Indian corn, bananas, sugar, cotton, &c. Live stock and poultry are also reared; and salt and fish are obtained in considerable quantities. The island derives its name from the pearls found here, the fishing of which formed a considerable part of the occupations of the inhabitants. This was principally carried on in the rocky islet of Coche, in the channel of Margarita; but this branch of industry has much declined of late, as the pearls are now neither so large in size nor so fine in quality as formerly. The principal manufactures of the island are those of cotton stockings and hammocks. A good deal of illicit traffic goes on between this island and the British and French possessions in the West Indies. Margarita is more thickly inhabited than any other part of South America; and there are several towns and villages in the island, the most important of which are, Assumpcion, the capital, which is a well-built town, not far from the centre, and Pampatar, a seaport on the S.E. This island was first visited by Columbus in 1498, and has in more recent times (1816) been the scene of a bloody warfare betwen the revolutionists and the Spanish troops under General Murillo, in which the latter were defeated. Pop. (1854), 23,967.

MARGARITONE, D'Arezzo, an Italian painter, sculptor, and architect of great reputation, was born at Arezzo in 1212. He belonged to the Greek school of art, and executed many pictures at his native place in tempera and in fresco. The most celebrated specimens of the latter style of painting executed by Margaritone were to be found in the church of San Clemente, afterwards destroyed by Duke Cosmo de' Medici when rebuilding the old walls of Arezzo. There still remain in Arezzo, however, a few specimens of the frescoes of this artist of great value. One of the most characteristic and important of these pictures was a work executed for the nuns of Santa Margarita, believed by some to be still recognisable among the Florentine pictures collected by the Signors F. Lombardi and Ugo Baldi. But of the "endless number of pictures," as Vasari phrases it, which Margaritone executed for his native city, the one on which the artist himself set the highest value, and "on which he placed his name," was a "San Francesco," painted for the convent of the Friars de' Zoccoli at Sargiano, a work which still exists with his own inscription of "*Margarit. de Aretio pingebat.*" He had a peculiar contrivance to prevent clefts and fissures in wood paintings. That the joinings might not appear after the painting had been completed, he covered the whole surface of the wood with canvas, secured with strong glue made from shreds of parchment, and next applied a layer of gypsum and glue to the outer surface of the canvas.

It is said that Margaritone succeeded better in sculpture than in painting. He improved upon his first efforts, which were executed in the Greek style, on coming in contact with the works of Arnolfo and other distinguished sculptors of Florence. Appointed to construct a tomb at Arezzo for Gregory X., who had died there, he executed a reclining statue in marble of that pontiff, still in good preservation, and a painting of his holiness, now entirely effaced. This masterpiece of art was considered "the best work he had yet produced." On the death of Maestro Lapo, who planned the episcopal buildings of Arezzo, Margaritone superintended the erection of the cathedral after the design of the original architect. A war between Arezzo and Florence in 1289 prevented the completion of this magnificent undertaking. Vasari is of opinion that it was this architect who planned the Governors' palace in the city of Ancona in 1270, and who executed the sculptured ornaments of the front windows of that beautiful edifice. He died at Arezzo in 1289, aged seventy-seven. (Lanzi, *Stor. Pitt.*)

MARGATE, a seaport, market-town, and watering-place of England, in the Isle of Thanet, county of Kent, is situated along the shore and on the slope of two hills, 3 miles W.N.W. of the N. Foreland, 15 miles N.E. by E. of Canterbury, and 72 E. by S. of London. The name of the town is believed to be derived from *Meregate*, a gate or opening to the sea; on account of the hollow between the two hills on which the town is built. Margate was till recently only a small village, and the older parts of the town which lie along the shore are irregularly and meanly built; but the upper part, which is more modern, contains several fine streets and squares, is well built and paved. It is principally noted as a fashionable watering-place, and is still very much frequented in the summer season, although the construction of railways to the seaports on the S. coast has somewhat diminished the number of its visitors. The parish church of St John is an ancient edifice, in the Gothic style; a modern church in the old English style, with a lofty tower, was built in 1825. There are also places of worship for Methodists, Presbyterians, Independents, Baptists, the Countess of Huntingdon's Connection, Society of Friends, and Roman Catholics. The assembly rooms of Margate are reckoned among the handsomest and largest buildings of the kind in England, and are adorned with a colonnade of Doric pillars. The town has also a fine theatre, as wall as baths, libraries, and other establishments for the convenience of visitors. The town-hall is of recent construction, and is supported on iron pillars, and fronted with a handsome portico. The harbour of Margate is dry at low water; and in order to obviate this defect, a stone pier, 900 feet in length, with a lighthouse at the end, was constructed at a cost of L.100,000. But this proving insufficient, a wooden jetty was also built, 1100 feet long, at which steamers can touch in all states of the tide, except when the weather is very stormy. The pier, the marine terrace, and the esplanade, form the most fashionable and most frequented promenades of Margate. The walks in the vicinity are numerous, and the scenery is very beautiful. Fishing is still carried on to a considerable extent here; and there is some trade with the Netherlands; but the prosperity of the town depends chiefly on the summer visitors. Margate communicates with London by a branch of the South-Eastern Railway, and steamers also ply by sea, performing the journey in six or seven hours. The market-days are Wednesday and Saturday. Pop. (1851) 9107.

MARGHILAN, or MARGINAN, a town of Independent Turkestan, is situated in a fertile plain, 25 miles S.E. of Khokhan. It is large and well built, surrounded by earthen ramparts, and containing a lofty and ancient tower, a caravanserai, and several mosques. Manufactures are carried on here of gold and silver articles, as well as silk and velvet, and the trade is considerable with Bokhara and Cashgar.

MARGRAVE. See LANDGRAVE.

MARIA ISLAND is situated between 2 and 3 miles from the E. coast of Van Diemen's Land, in Lat. 42. 40. S., Long. 148. 10. E. It is about 12 miles in length from N. to S., by 7 in extreme breadth. It consists of two parts, connected by a low and narrow neck of sand, almost covered at high water, but it rises at either extremity into mountains. On each side of the isthmus there is a large bay,—that on the W. being called Oyster Bay, and that on the E. Reidle Bay. The shores of the island abound in seals and zoophytes, and immense quantities of sea-weeds, growing up from a depth of 250 or 300 feet, impede navigation. The geological structure of Maria Island is principally of trap; but on the E. coast perpendicular cliffs of granite rise to the height of 300 or 400 feet from the sea; and as they are pierced by many large caverns, the sea rolls in with a noise resembling thunder. On the other side of the island the land slopes gradually down to the sea-level. The soil of the interior is rich and productive, and the scenery extremely picturesque. On the northern extremity is situated the valley of Darlington. This island was discovered by Tasman in 1642.

MARIA THERESA, daughter of Charles VI. of Austria, Queen of Hungary and Bohemia, and Empress of Germany, was born at Vienna on the 13th of May 1717. By the Pragmatical Sanction of 1724 her father had regulated the succession in the family of Austria, and failing of male issue his daughter Maria was declared heiress of the Austrian monarchy; a settlement which was guaranteed by the principal states of Europe. In 1736 Maria Theresa married Francis-Stephen of Lorraine, afterwards Grand Duke of Tuscany, and on the 20th October, 1740, on the death of her father the Emperor Charles VI., she succeeded to the throne of Hungary and Bohemia, and the other hereditary states of her house, her husband being declared co-regent. No sooner had she ascended the throne than she was assailed by the kings of Prussia, France, Spain, Sardinia, and the electors of Bavaria and Saxony, who conspired to dismember the Austrian dominions and seize upon the portion of her territory to which each of those powers asserted a claim. Frederick of Prussia demanded Silesia, and on meeting with the indignant refusal of the brave young empress, marched his troops into that province. Charles Albert of Bavaria, assisted by the French, moved direct upon Vienna, and compelled Maria Theresa to quit her capital. At this juncture the aspect of her affairs was depressing in the extreme. Her kingdom exhausted, her people discontented, an empty treasury, and an army reduced to 30,000 men, with all her neighbours up in arms against her, and with a husband weak in intellect and destitute of energy,—this spirited empress of twenty-three turned resolutely upon her foes, appealed to the chivalrous enthusiasm of her brave Hungarians, and bade defiance alike to Frederick of Prussia and her kinsman of Bavaria. On quitting her capital, she repaired to Presburg, and summoning the diet of Hungary, she appeared in the midst of the assembly with her infant son in her arms. She addressed them in Latin with great eloquence, and on exclaiming, "Forsaken by all, we seek shelter only in the fidelity, the arms, the hereditary valour, of the renowned Hungarian nobility," that martial assembly shouted, as their swords leapt from their scabbards, "Let us die for our *king* Maria Theresa." (*Moriamur pro Rege nostro Mariâ Theresâ.*) The Hungarian nobles mounted horse, brought their whole military force into the field, and, in conjunction with the gallant troops of General Kevenhuller and Prince Charles of Lorraine, succeeded in driving the French and Bavarians beyond the dominions of their sovereign. Her numerous enemies were gradually silenced, and the current of invasion no longer set against her. She was constrained, however, to come to terms with Frederick of Prussia, by ceding to him Silesia; but she made a treaty of alliance with Sardinia against France and Spain; and the elector of Saxony, who had also made peace with her, subsequently rendered her material service when her old enemy of Prussia found fresh cause for invading the Austrian dominions. On the death, in 1746, of Charles Albert, who had been elected Emperor of Germany by the Frankfort diet, Maria Theresa's husband, the Grand Duke Francis, was raised to the imperial throne. Meanwhile the Austrian and Piedmontese troops were attended by signal success in Italy; they overthrew the French and Spaniards at Piacenza, and gained a temporary possession of Genoa, when after much hard fighting in Italy and Flanders, the peace of Aix-la-Chapelle, in 1748, closed the war of the Austrian succession, and left Maria Theresa in possession of all her territories except Silesia. Deeply mortified by the loss of the latter province, the indefatigable empress joined France and Russia, and embarked with fresh energy in the Seven Years' War against Frederick of Prussia, in the hope of recovering that portion of her territories which the war of the succession had taken away. But 1763 saw the termination of this contest, and left the great Prussian still in possession of the province of his Austrian neighbour. Maria Theresa lost her husband in 1765, and her son Joseph was immediately elected emperor. Yet this vigorous woman continued to retain the administration of her extensive possessions during her life, and showed much solicitude for the welfare of her people, and marked enlightenment in the measures proposed for their improvement. Although a sincere Roman Catholic, she nevertheless employed a firm hand in drawing the line of demarcation between temporal and spiritual jurisdiction. She checked the arbitrary power of the Inquisition, and the ultimate abolition of that obnoxious institution in Lombardy and Tuscany, under her sons Joseph and Leopold, was only the legitimate development of the system of reform conceived and set on foot by their imperial parent. She reformed various abuses in the church, repressed the Jesuits, abolished the torture, encouraged the arts, advanced agriculture, and instituted universities and schools of which many still bear her name. The great stain in the political character of Maria Theresa is the part which she took in the partition of Poland. Yet it is said she left a written record of her sense of the injustice of this act, and of the manner in which she was induced to consent to the measure. She at first refused acceding to the treaty of partition framed by Russia and Prussia in 1772, but being afterwards informed that the dismemberment of Poland would be effected without her consent, and that her own possessions would be thereby imperilled, she, in compliance with the urgent importunities of Prince Kaunitz and her son the Emperor Joseph, agreed to take part in the foul wrong about to be inflicted on that unhappy country. Irreproachable in her private character, she gave a tone and elevation to the morals of her court, by which it stood out in bright contrast to the profligate courts which disgraced the contemporary sovereigns of Europe. In short, Maria Theresa ranks unmistakeably among those sovereigns whom mankind remember with admiration, and she will ever occupy an honourable place amid the select band of the world's illustrious women. She died at Vienna on the 29th November 1780, leaving a family of five sons and ten daughters to mourn her loss. With Maria Theresa ended the dynasty of Hapsburg. (See AUSTRIA.)

MARIANA, JOHN, a celebrated Spanish historian, born in 1537, at Talavera, in the diocese of Toledo. He studied with distinction at the university of Alcala, and was admitted, at the age of seventeen, into the Society of Jesus, where he soon attracted notice by the vivacity of his disposition and the extent of his acquirements. Called to Rome in 1561, he there professed theology during four years, and reckoned among his pupils young Bellarmin, afterwards the celebrated cardinal. He then passed into Sicily, where he remained two years. In 1569 his superiors sent him to Paris, and he there explained the doctrines of St Thomas, in presence of a great concourse of auditors attracted thither by his reputation. But the decline of his health, occasioned by vigils and fatigues, having forced him to renounce teaching, he, in 1574, obtained permission to return to Spain. He retired to the house of the Jesuits at Toledo, and there he composed the works which, in adding to his celebrity, disturbed the peace of his life. Mariana displayed too much liberality and candour for his age. If he censured regal vices in his work *De Rege*, he was accused of treason; and if in *Del Gobierno de la Compañia* he pointed out the defects of his order, he excited the bitterest animosity of the Jesuits, and had his books burnt for his pains. He bore with patience, however, the criticisms and persecutions to which he was exposed, and died on the 17th of February 1624, at the age of eighty-seven.

The great work of Mariana is entitled *Historiæ de Rebus Hispaniæ, libri* XXX. *cum Appendice.* The first twenty books of this history, which terminates at the year 1428, were printed at Toledo, in 1592, folio, and the five following books in 1595. The success of this work induced the author himself to translate it into Spanish; and he at the same time made considerable changes in and additions thereto. The most esteemed Latin edition is that of the *Hague*, 1733, in two volumes folio, with the continuation of Jose Emmanuel Miniana from 1516, where Mariana stopped, to the year 1609. Amongst the Spanish editions the most beautiful of all is that of Valentia, 1783–1796, in 9 vols., accompanied with chronological tables, and enriched with critical notes and observations. The history of Spain by Mariana is esteemed for the extent of the author's researches, the general exactness of his facts, the sagacity of his reflections, and, above all, for the merit of his style, in which, in simplicity and elegance, he makes a nearer approach to Livy than do the most of modern historians. Mariana, however, has been reproached with neglecting to cite his authorities, and sometimes drawing on his imagination to supply defects in historical documents; and he has also committed some errors, which were exposed with much bitterness by Father Mantuano, secretary to the Constable of Castille, in his *Advertencias a la Historia de J. de Mariana*, Milan, 1611, in 4to, a work which Tamaio de Vargas endeavoured to refute.

The other works of Mariana are,—*De Rege et Regis Institutione libri tres*, Toledo, 1599, in 4to; the original edition of a work famous in its day, and now much sought after by the curious; *Liber de Ponderibus et Mensuris*, Toledo, 1599, in 4to; *Tractatus Septem, Theologici et Historici*, Cologne, 1609, in folio; *Scholia brevia in Vetus et Novum Testamentum*, Madrid, 1619, in folio, a work commended by Simon, who pronounces Mariana one of the most able and judicious commentators on the Holy Scriptures. He also wrote *A Treatise of some things which require to be Amended in the Company of Jesus*, Paris, 1625, in 8vo, reprinted with the Spanish text in the *Mercure Jésuitique.* This work was found amongst the papers of Mariana during his detention, and some copies of it were taken, which the enemies of the Society multiplied in France, in Italy, and in Germany. The Jesuits obtained its condemnation in 1631; but it is very doubtful whether Mariana had any share in the redaction of the obnoxious publication. Mariana left in manuscript several works, of which a catalogue will be found in the *Bibliothèque des Jésuites.* His

Historiæ was translated into English by Stevens, folio, London, 1699.

MARIANNA, or MARIANA, a town in the province of Minas-Geraes, Brazil, pleasantly situated between two eminences, at a height of 3000 feet above the sea, 45 miles N.E. of Ouro-Preto. The town is well built; and the principal streets are broad and well paved. The principal buildings are,—a cathedral, several other churches and convents, an ecclesiastical seminary, an hospital, and the bishop's palace. The trade is inconsiderable. Pop. 5200.

MARIANNE ISLANDS. See LADRONE.

MARIAS, LAS TRES, three islands in the North Pacific Ocean, lying off the W. coast of Mexico, and belonging to the state of Xalisco; between 21. and 22. N. Lat., and 106. and 106. 30. W. Long. They stretch in a line from N.W. to S.E.; and the largest of the three, which is the furthest to the N.W., is about 15 miles in length and 8 in breadth. The next island is about 24 miles in circumference, and the smallest, which lies to the S.E., has a circuit of 8 miles. These islands are barren and uninhabited, but they abound in wood, water, salt, and game, and were formerly often visited by English and American whaling vessels. They were visited by Diego de Mendoza in 1532, and named by him Isles de la Magdalena.

MARIAZELL, or ZELL, a market-town of Styria, circle of Bruck, is situated in the midst of mountainous and picturesque scenery, near the confines of Austria, about 55 miles S.W. of Vienna. It is only remarkable for a shrine of the Virgin, which every year attracts about one hundred thousand pilgrims. The town is meanly built, and contains about one hundred and twenty houses, of which forty-four are inns for the accommodation of pilgrims. Near the town are extensive iron-works. Pop. about 900.

MARIE ANTOINETTE, the daughter of Francis I., Emperor of Germany, and of the celebrated Maria Theresa of Austria, was born at Vienna 2d November, 1755. She had scarcely completed her fourteenth year, when the Duke de Choiseul was entrusted by Louis XV. to ask her in marriage for his grandson, the Dauphin of France, who afterwards, in 1774, became king under the name of Louis XVI. The marriage was celebrated at Versailles on the 10th of May 1770. But Marie Antoinette was not destined to experience much happiness at the corrupt court of France. Habituated from her earliest years, at the well-regulated court of Maria Theresa, to the enjoyment of privacy and domestic familiarity, she felt a strong dislike to the severe etiquette and stiff reserve which at the French court usurped the place of that candour and simplicity which almost invariably accompany purity of heart and true nobility of character. What was genuinely pure and noble was wellnigh unknown there; and gay frivolity and wanton licentiousness assumed a guise which was in some measure calculated to deceive the eye of the virtuous. This handsome, kind-hearted, lively and pure-minded German girl could with difficulty conceal her contempt for the heartless society among which she was cast. Prudence might have dictated less demonstration of her ridicule, less ostentation of her love for private life and the sweets of domestic affection; but her disposition was too spontaneous, her habit of mind too thoughtless for such a course, and she was consequently destined to multiply enemies rather than secure friends. Yet there was much in the young queen to attract the enthusiasm of her volatile subjects. If she disliked the stiff formality and polite insincerity of the court, her noble carriage and charming expression won the hearts of the people. When she appeared at first in public, the enthusiastic admiration of the populace was unbounded, and she had often to stand on the steps of her carriage and show herself to the admiring throng. But this interest was gradually dying away before the growing discontent of a distressed people, caused by the luxury of the court, and the exhaustion of the public treasury, when an incident occurred which gave the first direct blow to the popularity of Marie Antoinette. The Countess de la Motte having become aware that the queen had declined the offer of a magnificent diamond necklace from her jeweller, owing to the enormous price of 1,800,000 livres, which he demanded for it, the crafty countess, anxious to obtain possession of the treasure, alleged that she was authorized by the queen, and concluded the bargain. This unprincipled woman succeeded, besides, by a dexterous piece of intriguing, in making the Cardinal de Rohan a party to the negotiation, by beguiling him into the belief that he was met at midnight by Marie Antoinette in the park of Versailles. The fraud was discovered when the first payment was demanded; and, although the infamous countess was condemned to be whipped and branded for the wrong she had done her royal mistress, public suspicion was awakened, and the tongue of scandal let loose against the queen, who is now universally believed to have been innocent of the crimes laid to her charge. At the outbreak of the Revolution in 1789 she was regarded with an eye of jealous dislike by the public. She is said to have used all her efforts to induce her feeble and irresolute husband to offer resistance, but without success. She scorned to conciliate the favour of the revolutionary leaders, and even declined the aid of Mirabeau to support the royal interest; a step which drove that powerful orator and extraordinary man to enlist in the ranks of the Revolutionists. Marie Antoinette was imprisoned in the Temple after the popular triumph of the 10th August, 1792. She became known as one of the advisers of the attempted flight of the king, and this served to increase the jealousy and hatred of the public. The armed masses were resolved to annihilate the kingly office, and the poor unfortunate queen was exposed to all manner of insult and persecution. Nevertheless, she was not of a temper to be at once crushed by adversity; she displayed a dignified courage under the most trying circumstances, and exhibited a degree of moral firmness and mild resignation which was truly heroic. She was ever more anxious about the welfare of her husband and of her children than she was about her own. The royal family, on going to prison, had tried to persuade themselves that Danton was their friend, but the bloody fanaticism of the mob, led on by *Ami du peuple* Marat, soon extinguished any rays of hope that still may have lingered about the prison walls of this unfortunate family. The king was executed on the 21st of January, 1793, and on the following October, the "widow Capet," as the indictment called her, was tried by the tribunal of the Revolution. On appearing before that horrible court, she felt her doom was sealed; that no plea of innocence could save her; yet her fortitude and queenly dignity never forsook her. The foulest and most infamous charges were brought against her, calculated to outrage her feelings as a woman and a mother. Being urged to reply, she exclaimed, turning to the public with vehement indignation, "I appeal to all the mothers here present, and demand of them if this is possible." "This stroke," says a French historian, "was sublime; it produced a great effect; and the president, perceiving this, passed hastily to the other questions." She was, as a matter of course, found guilty and condemned to death; and on the 16th of October, 1793, she was removed from the prison of the Conciergerie, and conducted, bound on a cart, beside a priest and the executioner, to the place of suffering. The foul mockery of her trial was only surpassed by the heartless brutality of the ferocious mob that yelled and vociferated around her for two hours along the streets of Paris. Her trying imprisonment and severe suffering had wasted her strength and destroyed her beauty; her eyesight was greatly injured, and her hair had become quite white. She bore all the indignities which were thus publicly heaped upon her with singular firmness and mild dignity, inspiring even that savage mob with wonder and awe. She died by the guillotine on the 16th October, at the age of thirty-seven. Out of a family of four, two children survived her; a son, who subsequently died in prison, and a daughter, who afterwards became the Duchess of Angoulême.

MARIE-AUX-MINES, St, a town of France, department of Haut-Rhin, is situated on the Lieporette, 14 miles N.W. of Colmar. The town stretches for about a mile on both sides of the river, and on each side rise thickly wooded mountains which look down upon it. It possesses a council of *prud'hommes*, a chamber of manufactures, and a Protestant church. The neighbouring district was rich in mines, which in the middle ages produced silver, lead, and copper, in great quantities, though there is now remaining only one mine of argentiferous lead. The principal occupations now pursued in the town consist of the manufacture of linen, cotton, and woollen stuffs, especially handkerchiefs and calicoes. Bleaching, dyeing, paper-making, and tanning, are also carried on to a considerable extent. Pop. 11,600.

MARIE GALANTE. See GUADALOUPE.

MARIENBERG, a town in Saxony, circle of Zwickau, is situated at a height of 1980 feet above the level of the sea, 17 miles S.S.E. of Chemnitz, and 38 S.W. of Dresden. The town contains a church; two hospitals, one for orphans and one for miners; several other charitable institutions; besides an office for mines and a custom-house. It is famous for its mineral baths, and for mines of silver, iron, &c., which are worked to a great extent in the neighbourhood. The manufacture of lace and linen is also carried on here. Pop. 4895.

MARIENBURG, a town of West Prussia, government of Dantzic, is situated on the right bank of the Nogat, a branch of the Vistula, here crossed by a bridge of boats 546 feet long, 27 miles S.E. of Dantzic. It is surrounded by walls, and is principally important and interesting as having been the residence of the grand masters of the Teutonic Order of Knights. The ancient castle of the Order, which comprises also a palace and a church, is a splendid edifice in the Gothic style. It seems probable that the oldest part of it was built in the thirteenth century, when the King of Poland made a grant of this country to the knights. Additions were subsequently made to it in 1309, when the seat of the Order was transferred hither from Venice, and in 1335. In 1457 the castle was surrendered to the Poles, after having sustained several unsuccessful attacks in 1410 and 1420. On falling into decay, it was in 1815 restored by the present King of Prussia, and has since been kept in good preservation. The chapter-house, where all the meetings of the knights were held, is supported by a single granite pillar; and during the siege in 1410 the Poles attempted the destruction of the knights by aiming a cannon ball at the supporting column, when they knew that the grand master and his knights were assembled in conclave. The ball, which narrowly missed its aim, is still shown buried in the corner of the building. The church is a fine edifice in good preservation, and is chiefly remarkable for a mosaic figure of the Virgin on the outside of the wall. In the vaults beneath are buried many of the grand masters of the Teutonic Knights; and an extremely beautiful picture of the Virgin, by an unknown artist, which is kept here, is believed to possess miraculous powers. The town possesses in the present day little importance. It has a Roman Catholic and a Calvinist church, a normal school, and other educational and charitable institutions; as well as manufactures of cotton and woollen fabrics, and some trade in corn and wool. Pop. 7037.

MARIENWERDER, a government of West Prussia, is bounded on the N. by that of Dantzic, on the E. by that of Königsberg, on the S. by Poland and Posen, and on the W. by Brandenburg, with an area of 6759 square miles. The surface is for the most part level, and in some places marshy; but there are a few small hills scattered about in different parts. Much of the country is of no great fertility, and is ill cultivated; but near the rivers the soil is rich and fertile. The principal rivers are the Vistula, which is navigable, and its tributary the Brahe. No considerable mining operations are carried on in this district; nor are manufactures or commerce in a very thriving condition. The government is divided into thirteen circles; and the capital is Marienwerder, a neat town situated on the Liebe and little Nogat, 2 miles E. of the Vistula, and 43 miles S.S.E. of Dantzic. The town is chiefly notable for its old castle, now used as a court-house and prison; and for the cathedral, which has a spire of the height of 170 feet, and contains many ancient tombs of the Teutonic knights. The town also possesses a gymnasium, a school of architecture, an asylum for blind soldiers, another for their widows and children, an hospital, and a house of refuge for neglected children. The manufactures are not very extensive, and consist principally of linen and woollen stuffs, leather, hats, beer, and wines. Pop. of the government (1852) 649,548, of the town 7600.

MARIETTA, a town in the state of Ohio, capital of the county of Washington, North America, is situated at the confluence of the Muskingum and the Ohio, 115 miles S.E. of Columbus, and stands in a plain, surrounded with beautiful and picturesque scenery. It is well and regularly built, being greatly adorned by the neat gardens with which many of the houses are surrounded. Marietta contains seven or eight churches, two public libraries, a college founded in 1835, and two excellent academies. Within the last eight or nine years several manufactories have been established here, which have added much to the importance of Marietta. This town is the oldest in the state, and was first settled in 1788 by a body of New England colonists under General Putnam. Pop. (1850) 3175, (1853) about 4000.

MARINEO, a city of the kingdom of Naples, in the island of Sicily, and province of Mazzaro. It is situated on a gentle elevation, is very healthy, and is watered by the small River Bagaria. It contains 6540 inhabitants.

MARINI, MONSIGNOR GÆTANO, a celebrated savant, born in 1742 at St Arcangelo, near Rimini, in the Papal States. He began his studies under Giovanni Bianchi, and in early youth devoted himself to natural philosophy. He then turned his attention to mathematics, Greek, Hebrew, and classic literature; and afterwards, at the suggestion of his intimate friend Zerardini, applied himself to the study of jurisprudence, and went to Ravenna, where he took his degrees in Roman and ecclesiastical law. He did not, however, feel disposed to practise that profession, his tastes tending rather to philosophical and antiquarian research. To obtain leisure for these studies, he went to Rome in 1764, took holy orders, and dedicated himself to archæology. At that time the science of archæology was at its height in Italy. The recent discovery of Pompeii and Herculaneum had attracted the attention of princes as well as of the learned. Count Caylus had already classified the ancient monuments; Johann Winkelmann and the members of the Herculanenses Society had with equal taste and learning illustrated them; Ennio Quirino Visconti, the Nestor of art critics, had made them popular. The civilized West now began to turn its attention to the East, the cradle of mankind; and some of the most learned men of the time at Rome were engaged in philological, antiquarian, and numismatic researches, directed mainly towards the most interesting fields of inquiry in Egypt and the Asiatic continent, when Marini resolved to enlist in their ranks, and share their reputation.

He undertook to examine the ancient papyri, and among his many works, *I Papiri Diplomatici raccolti ed illustrati*, Roma, 1805, is that which principally entitles him to a high place among the savants of the eighteenth century. The first idea of this work belongs to Scipione Maffei; and though Zcrardini had previously attempted it, the honour of having accomplished this arduous task belongs entirely to Marini. It contains 146 Latin, and a few Greek diplomas or charters, extracted from papyri which he collected in Italy, France, and Vienna. Among these may be found papal letters addressed to the exarchs of Ravenna, charters by the Emperor Valentinian, by Chlodoveus, by Dagobert and Clothaire, kings of the Franks, by King Astolph and Adalgiso, interspersed with many other public and private documents. "Learned men," he says, "know the wonder felt by the ancients when they saw papyri two or three centuries old, but among ours there are some which date back fourteen or fifteen centuries." The oldest in fact belongs to the year 444. They were in a most dilapidated condition, and their interpretation is a monument of patience, talent, and learning. The researches which accompany this work, especially on the cultivation, traffic, and general use of the papyrus in Italy until the close of the eleventh century, even after the introduction of parchment, are very interesting and valuable.

Marini's next most important work is *Gli Atti de' Fratelli Arvali*, Roma, 1795, 2 vols. 4to, in which he collected and illustrated all the inscriptions and monuments which relate to the *Collegium Fratrum Arvalium*, an institution which, according to tradition, was coeval with the building of Rome, and founded, as Varro tells us, to propitiate the Divinity by public prayers, that the land might be rendered fertile (*sacra publica faciunt propterea ut fruges ferant arva*); whence *Arvales Fratres* or *Arvorum Sacerdotes*. This work is admirable for the acumen and learning displayed. The immediate cause of Marini's undertaking to investigate this subject was the discovery of two large marble tablets in the new sacristy of the Vatican chapel, which had been built by order of Pius VI. From these and various other inscriptions and monuments connected with that institution, he was enabled to find a clue to the ceremonies, rites, and fêtes; also the political connection of that remarkable body with the state, and hence to study their civil institutions, the duty of their municipal functionaries and provincial governors, to correct names, to determine the genealogy of many Roman families, &c., &c.; while discussions on ancient orthography, on the variation between the spelling and the pronunciation, the correction of old abbreviations in inscriptions, and the additions of new ones, find an appropriate place in this laborious and comprehensive work.

Marini's contributions to the scientific and literary history of Italy, to numismatics, to the elucidation of the Christian and pagan monuments, and of many unpublished documents in the Vatican, are all marked by the same sound criticism and unobtrusive but deep erudition. The most important of his minor works is that on the inscriptions in the Albani villas and palaces.

He obtained a well-earned celebrity both in Italy and abroad, and had honours and high offices conferred on him by several popes. He was appointed keeper of the *Biblioteca Vaticana* and prefect of the secret archives of the Holy See, was elected a member of the Institute of France and of the *Academie des Inscriptions et Belles Lettres*, as well as of all the scientific, literary, and archæological societies of Italy. He died at Paris on the 17th of May 1815, in his seventy-third year. (E. F.)

MARINO, San, or Sammarino, a republic in the N.E. of Italy, bounded on all sides by the Papal States, and situated about 10 miles from the Adriatic; area 24 square miles. It is not only the smallest in extent, but it is also the oldest of all the European states. In the year 469 Marinus, a Dalmatian hermit, originally a mason, is said to have settled here in the solitude of the mountains; and, having obtained from the owner a grant of territory, he was joined by a number of similar devotees, and thus gave origin and name to the little republic of San Marino. A village rose gradually; and in the tenth century it became a walled town, continuing independent of all foreign powers. In the civil wars of Italy, San Marino embraced the side of the Ghibeline or imperial party, and in the thirteenth century refused to pay certain taxes imposed by the pope. A dispute thereupon arose, which, on being referred to a learned judge of that day, was decided in favour of the republic; and San Marino has ever since been recognised by the popes as an independent state. Nor was any change made either on the conquest of Italy by Napoleon, or on the reinstatement of the pope in 1814. The legislature of the state consists of a large council of sixty, made up, in equal proportions, of nobles, townsmen, and small proprietors. This council is self-elected, and the members are chosen for life. Out of this a smaller council of twelve is chosen, and the executive power is in the hands of two *capitani reggenti*, who hold office for six months. The territory of the republic is entirely mountainous, and is watered by the Ausa and the Amarano, small streams which fall into the Adriatic. It produces wine, fruits, and silk. The town of San Marino, which stands on a mountain, the summit of which is crowned by a castle, is ill built and paved; and the streets are so steep as to be inaccessible for horses or carriages. The town has five churches, three convents, a town-house, and a large square commanding an extensive view. Besides the capital, San Marino has four villages. Pop. of state 7600.

MARIOTTE, Edme, a natural philosopher, was born in Burgundy in the seventeenth century. During part of his life he dwelt at Dijon, and from that place his first works are dated. He had studied for the church, and was afterwards chosen prior of St Martin, near Beaune. On the formation of the Academy of Sciences he became one of its members. He died in 1684. Mariotte was among the first French philosophers who turned their attention to experimental physics. In 1717 there was published at Leyden, in 2 vols. 4to, a collection of his works, comprising Treatises on Vegetation, on the Nature of the Air, on Heat and Cold, on the Nature of Colours, on Hydraulics, on a New Discovery touching the Sight, on Levelling, on the Motion of the Pendulum, on the Colours and Congelation of Water, and on Logic. (For an account of Mariotte's experiments on the density of the air, see *Dissertation Fifth*, ii. 2.)

MARITZA, a river of European Turkey. (See Hebrus.)

MARIUS, Caius, a celebrated Roman general, was born about B.C. 157, of poor parents, in Cereatæ (Plin. iii. 5.), a village near Arpinum, afterwards famous as the native town of Cicero. His youth seems to have been passed amidst the rude discipline of the camp; nor was his disposition at all softened by literature or by intercourse with the learned. He commenced his military career at Numantia (B.C. 134), and by his temperance and bravery so won the good opinion of Scipio, that that general answered one of his friends who inquired where they would find another general equal to himself, by putting his hand on the shoulder of Marius and saying, "Here he is." Many years, however, pass without any allusion to Marius, nor do we know what part he took in the troubled times of the Gracchi. He appears again in history as tribune of the people, B.C. 119, which office he is said to have obtained chiefly through the influence of the consul Metellus, whose implacable enemy he afterwards became. He began immediately to court the favour of the people, and proposed a law which tended to lessen the authority of the patricians in matters of judicature. The consul Cotta persuaded the senate to summon Marius to answer for his conduct; but the bold tribune threatened to send even the consuls to prison if they persisted in opposition to his measure. The senate gave way, and the law was subsequently confirmed by the people. He was thus supposed to have embarked in the popular cause; but this opinion changed when it was found that he strenuously opposed the distribution of corn amongst the people. When his year of office had expired, he stood as candidate for the curule ædileship, but was rejected; upon which he applied for the plebeian ædileship, and in this too he was unsuccessful. Not long afterwards he stood for the prætorship, and was returned last of the six, and not without the suspicion of bribery. He was tried, and escaped only by an equality of votes. The following year he was sent as proprætor to Farther Spain, which he soon cleared of the banditti who infested the province. On his return to Rome he was anxious to take part in the administration of public affairs, but he had neither riches to buy favour, nor eloquence to command it. Still, by his high spirit, by his indefatigable industry, and simple mode of living, he became a favourite with the people, and acquired sufficient reputation to be thought worthy of marrying Julia, the aunt of Julius Cæsar. When Metellus was appointed, B.C. 108, to the command of the war against Jugurtha, he chose Marius as one of his lieutenants. Selfish enough to feel no gratitude for his promotion, and to be wholly intent upon his own advancement, Marius strove by every method to convince the soldiers of the faults of Metellus, and of the merits of himself. When he had thus succeeded in persuading all that he alone was able to terminate the war, he determined to stand as candidate for the consulship, and pressed Metellus to grant him leave of absence to proceed to Rome. Metellus ridiculed his pretensions to such a high office, and, laughing, asked him if he would not be satisfied to stay and be consul with his son, who was then very young. At last, however, he granted permission only twelve days before the election; but favoured by the winds, Marius reached Rome in six days. His recently acquired fame had gone before him, and the people elected him consul, B.C. 107, with great applause. He was commissioned to supersede Metellus in the province of Numidia; and while levying an army, he enlisted, in opposition to the usual custom, all persons, however ignoble, who offered themselves. He then returned with his troops to Africa, but did not reap the glory which he had expected, for he was in a great measure deprived of it by his quæstor Sylla. Jugurtha had fled to his father-in-law Bocchus, King of Mauritania; and that prince, after some deliberation, delivered him alive (B.C. 105) into the hands of Sylla. (See JUGURTHA.) It was this circumstance which laid the foundation of that violent and implacable quarrel between Marius and Sylla which almost ruined the republic. Italy was at this time threatened by an invasion from the Cimbri and Teutones, a horde of northern barbarians who had overrun the whole of Gaul. The Romans were in the utmost consternation, and no one seemed able to protect them but Marius. Though absent, he was elected consul a second time, B.C. 104, and received orders to return home with his army. On his arrival he obtained the honours of a triumph, and then devoted himself to the discipline of the levies which he raised. The barbarians meanwhile had passed into Spain, and during the whole of this year Italy had a respite from her enemies. At length, in 102 B.C., shortly after Marius had been elected consul for the fourth time, they approached with an overwhelming force the northern frontiers of Italy. Marius hastened across the Alps, and pitched his camp near the mouth of the Rhone. The camp was fortified and well provisioned; and, that it might communicate with the sea, he employed his men in making a canal capable of receiving ships of considerable burden. Meanwhile the barbarian army had divided. The Cimbri marched in the direction of the Tyrol to attack Catulus. The Teutones and Ambrones advanced to storm the camp of Marius. That general, in order that his army might become inured to the wild aspect of the savages, remained inactive until they were compelled by lack of provisions to abandon the siege, and press forward to Italy. He then left his camp, hovered about their rear, and seizing a favourable opportunity, attacked them at Aquæ Sextiæ (*Aix*), and after a desperate conflict, routed them with immense carnage. The wives and those who had escaped from the battle put an end to their lives. Whilst he was sacrificing in honour of this victory he received intelligence that he had been elected fifth time consul, B.C. 101.

Marius returned to Rome, where he was offered a triumph, which he declined. He then proceeded to the assistance of his late colleague Catulus, who was guarding the north of Italy against the Cimbri. His arrival gave confidence to Catulus; and as soon as the army from Gaul arrived, they crossed the Po to check the barbarians who were ravaging the country on the opposite side. The Cimbri deferred the combat till the arrival of the Teutones, whom they were unwilling to believe to have been destroyed; and in the meanwhile sent to demand lands and cities from Marius, which should be sufficient for themselves and brethren. "Your brethren," said Marius, "have land enough which we have already given them, and they shall have it for ever." A decisive battle was fought a short time afterwards (30th July) in the plain of Vercellæ; and though the victory was almost wholly due to the bravery and good conduct of Catulus, Marius carried off all the honour, and was named the third founder of Rome. On his return to Rome he enjoyed the honour of a triumph, along with his colleague Catulus. He then began to exert all his influence to get himself re-elected to the consulship, and he omitted no means, however dishonourable, that might conduce to his success. Marius succeeded (B.C. 100) for the sixth time, and one of his first acts was the banishment of his old enemy Metellus by a mean and treacherous device. So unpopular had Marius now become, that he refused to stand as a candidate for the censorship, lest he should suffer a repulse. Metellus was recalled next year, and that he might not witness his triumphant entrance, Marius left Rome for the East, under the pretence of performing some vow to the mother of the gods, but in reality to excite Mithridates against the Romans. For ten years Marius was disconnected with public affairs; but when the Marsian or Social War broke out (B.C. 90), he was appointed to the command. Age, however, had quenched his martial ardour, and his reputation suffered as much as that of Sylla increased. When the Social War had been concluded, B.C. 88, the Romans saw that they must commence the contest with Mithridates. The enmity of Marius and Sylla now broke out in open war, as they were both anxious to be appointed to the command. Sylla was supported by the senate, but Marius excited a sedition through the tribune Sulpitius, and received the appointment; on which Sylla, refusing to lay down his command, and backed by his whole army, marched to Rome and overawed his enemies. Marius with great difficulty embarked on board a small vessel at Ostia, which was ready to sail for Africa, but contrary winds obliged him to land at the mouth of the Liris (*Garigliano*) where he was abandoned by the sailors. There he was discovered lurking in a marsh, and was dragged to Minturnæ with a rope round his neck, and with his face and garments begrimed with mud. The authorities of the town resolved to put him to death, but could find no man willing to accomplish their wish. At length a Cimbrian horse-soldier offered his services, and entered the room of the captive with his sword drawn in his hand. But when Marius, fixing upon him his commanding eye, exclaimed, Marivaux.

"Dost thou dare to kill Marius?" he flung down his weapon and fled. The people of Minturnæ then persuaded their magistrates to banish Marius, and a vessel was found to bear him from his country. He proceeded to Ænaria (*Ischia*), and thence to Africa. He landed at Carthage; and whilst he was seated there, a messenger came from the governor Sextilius with an order that he should leave the province. "Go and tell him," said the unfortunate man, "that you have seen the exiled Marius sitting on the ruins of Carthage." Marius proceeded to Cercina, a small island not far from the continent, and here received intelligence that the consuls Cinna and Octavius, having quarrelled, had had recourse to arms. Marius determined to proceed to the assistance of Cinna, who had been driven by his colleague from Rome; and landing with a considerable body of exiles, he soon changed the face of affairs, and reinstated Cinna in his office. He himself refused to enter Rome till the decree of his banishment was repealed. This affected deference to the laws of his country was soon laid aside, and the streets of Rome flowed with the blood of the best of her citizens. Marius was elected consul for the seventh time, B.C. 86; but his age and infirmities rendered him little able to sustain the weight of public affairs. The intelligence that Sylla was returning victorious from the Mithridatic war alarmed him, and drove him for relief to intoxication. This hastened his end, and he died on the seventeenth day of his seventh consulship, B.C. 86, at the age of seventy. His ashes were thrown into the Anio by the order of Sylla. The Life of Marius has been written by Plutarch; that by Rutilius Rufus has been lost. An account of the proscription of Marius may be found in Appian.

MARIVAUX, PIERRE CARLET DE CHAMBLAIN DE, one of the most prolific and ingenious writers of the eighteenth century in the department of comedy and romance, was descended from an ancient family of Rouen, and was born at Paris in the year 1688. Young Marivaux early gave evidence of the subtilty and activity of his genius, which was carefully developed by all the appliances of an excellent education. The society to which he was introduced on his entrance into life exercised a sensible influence on the character of his writings. Admitted into the *salons* of the opulent females of the capital, who then vied with each other in protecting men of letters, he there contracted that affectation of wit, of which the comedies of Molière had not yet entirely cured the *précieuses* of the age. It was there that he became acquainted with Lamotte and the numerous writers who composed the salon of Madame de Tencin, and whom that celebrated woman familiarly called her "beasts." It was in this society that Marivaux, naturally inclined to controversy, and fond of paradox, though otherwise gentle and tolerant, amused himself in tilting with the partisans of antiquity, depreciating poetical talent, and deriding the admirers of Voltaire. He even went so far as to maintain that Molière did not understand comedy, and pretended that he could not conceive how people should admire the *Tartuffe* and the *Femmes-Savantes*. Living in the world at a period when Pyrrhonism in matters of religion was the fashion, he combated, without asperity, but with laudable zeal, that truly deplorable mania. "Ah, my God," said he on one occasion to a freethinker, who was otherwise an honest man, "take not from poor humanity that consolation which Providence has reserved for it." If he was slightly tinctured with vanity, he was also distinguished for magnanimous disinterestedness and severe probity. He died at Paris on the 12th of February 1763, at the age of seventy-five. He had been unanimously admitted a member of the French Academy in 1743, and had Voltaire for a competitor. Marivaux's dramatic pieces, while displaying much talent, are nevertheless inferior to his romances. He never surpassed his *Marianne*, or his *Paysan Parvenu*; delineations which, although characterized by the peculiar manner of the writer,—what the French call *marivauxdage*,—yet interest and charm the reader by their subtle knowledge of the human heart, and by their accurate and masterly touches of character.

To the Théâtre-Italien he contributed.—*L'Amour et la Vérité*, 1720; *Arlequin poli par Amour*, 1720; *La Surprise de l'Amour*, 1722; *La Double Inconstance*, 1723; *Le Prince Travesti*, 1724; *L'Ile des Esclaves*, 1725; *L'Hérétier de Village*, 1725; *Le Triomphe de Plutus*, 1728; *La Nouvelle Colonie, ou la Ligue des Femmes*, 1729; *Jeux de l'Amour et du Hazard*, 1730; *Le Triomphe de l'Amour*, 1732; *L'Ecole des Mères*, 1732; *L'Heureux Stratagème*, 1732; *La Méprise*, 1734; *La Mère Confidante*, 1735; *Les Fausses Confidences*, 1736; *La Joie Imprévue*, 1738; *Les Sincères*, 1739; and *L'Epreuve*, 1740. The dramatic works of Marivaux, originally represented at the Théâtre-François, are somewhat less numerous. They consist of *Annibal*, a tragedy, 1720; *Le Denouement Imprévue*, a comedy, 1724; *L'Ile de la Raison, ou les Petits Hommes*, derived from the romance of Gulliver, 1727; *La Surprise de l'Amour*, 1727; *La Réunion des Amours*, 1731; *Les Serments Indiscrets*, 1732; *Le Petit-Maître Corrigé*, 1734; *Le Legs*, 1736; *La Dispute*, 1744; and *Le Préjugé*, 1746. His romances consist of,—*Don Quichotte Moderne; Effets Surprenants de la Sympathie; La Vie de Marianne; La Paysan Parvenu; Le Philosophe Indigent*. His works were collected and published in 12 vols., Paris 1781, in 8vo.

Mark.

MARK, ST, *the Evangelist*, is, according to ecclesiastical testimonies, the same person who, in the Acts, is called by the Jewish name John, whose Roman surname was Marcus (Acts xii. 12, 25). He was a convert from Judaism, and the cousin of Barnabas, and was most probably of Jewish descent. We find his mother Mary a resident in Jerusalem, and entertaining the apostles at her house (Acts xii. 12). He accompanied Paul and Barnabas on their travels as an assistant (Acts xii. 25; xiii. 5), but afterwards left them and returned to Jerusalem. On this account Paul refused to take Mark with him on his second apostolical journey, but subsequently became reconciled to him, and he was present with the apostle during his captivity at Rome.

There is a unanimous ecclesiastical tradition that Mark was the companion and ἑρμηνευτής of Peter. This epithet, according to A. Tholuck, was applied to Mark because he was the assistant of Peter, and either orally or in writing communicated and developed what Peter taught. This tradition is the more credible, as the New Testament does not contain any passage that could have led to its invention; and, moreover, the testimony in favour of the connection between Mark and Peter is so old and respectable, that it can with difficulty be called in question. It first occurs at the commencement of the second century, and proceeds from the presbyter John (Euseb., *Hist. Eccles.* iii. 39); it afterwards appears in Irenæus (*Adv. Hær.* ii. 1. 1, and x. 6); in Tertullian (*Contra Mart.* iv. 5); in Clemens Alexandrinus, Jerome, and others. Eusebius infers (*Hist. Eccles.* ii. 15) from the later life of Mark, that he was with Peter at Rome. Epiphanius and others inform us that he introduced the gospel into Egypt, founded the church at Alexandria, and that he died in the eighth year of Nero's reign. This apostle is the author of the gospel which goes by his name.

MARK, ST, *Gospel of*, the same ancient authors who call Mark a μαθητής (disciple) and ἑρμηνευτής (secretary) of Peter, state also that he wrote his gospel according to the discourses of that apostle. The most ancient statement of this fact is that of the presbyter John and of Papias, which we quote from Eusebius (*Hist. Eccles.* iii. 39) as follows:—"Mark having become secretary to Peter, whatever he put into style he wrote with accuracy, but did not observe the chronological order of the discourses and actions of Christ, because he was neither a hearer nor a follower of the Lord; but at a later period, as I have said, wrote for Peter to meet the requisites of instruction, but by no means with the view to furnish a connected digest of the discourses of our Lord." Schleiermacher, and after him Strauss, have turned this into an argument against the gospel of Mark. They assert that this gospel is a συντάξις, which, if not chronological, is at least a concatenation according to the subjects. Now the presbyter John states that Mark wrote οὐ τάξει, *without order*. We learn, however, from what Papias adds, how Papias himself understood the words of the presbyter; and we perceive that he explains οὐ τάξει by ἔνια γραψας, *writing isolated facts*. Hence it appears that the words οὐ τάξει signify only incompleteness, but do not preclude all and every sort of arrangement.

If the opinions concerning the relation of Mark to Matthew and Luke, which have been current since the days of Griesbach, were correct, we might be able to form a true idea concerning the chronological succession in which the first three gospels were written. The chronological order of the gospels is, according to Origen, the same in which they follow each other in the codices. Irenæus (*Adversus Hæreses*, iii. 1.) states that Mark wrote after the death of Peter and Paul; but, according to Clemens Alexandrinus (*Hypotypos.* vi.) and Eusebius (*Hist. Eccles.* vi. 14), he wrote at Rome while Peter was yet living. Griesbach, Saunier, Strauss, and many others, however, state it as an unquestionable fact, that the Gospel of Mark was merely an abridgement of the Gospels of Matthew and Luke. Weisse, Wolke, and Bauer, on the other hand, have in recent times asserted that the Gospel of Mark was the most ancient of all the gospels, that Luke amplified the Gospel of Mark, and that Matthew made additions to both.

We do not see any reason to contradict the unanimous tradition of antiquity concerning the dependence of Mark upon Peter. We deem it possible, and even probable, that Luke read Mark, and that he also alludes to him by reckoning him among the *many*, who had written gospel history before him. This supposition, however, is by no means necessary or certain; and it is still possible that Mark wrote after Luke. Some of the ancient testimonies, namely, those of Irenæus, Clemens Alexandrinus, Jerome, and others, state that Mark's gospel was written at Rome. In favour of this opinion there have been urged some so-called Latinisms; for instance, in ch. xv. 15, and ch. v. 23. These expressions are, however, rather Græcisms than Latinisms. Others appeal to words which have a Latin origin; but these are military terms which the Greeks adopted from the Romans. These Latinisms cannot prove much, however, respecting the locality in which Mark's gospel was written; but it is certain that it was written for Gentile Christians. This appears from the explanation of Jewish customs (ch. vii. 2, 11; xii. 18; xiii. 3; xiv. 12; xv. 6, 42). The same view is confirmed by the scarcity of quotations from the Old Testament, perhaps also by the absence of the genealogy of Christ, and by the omission of the Sermon on the Mount, which explains the relation of Christ to the Old Testament dispensation, and which was, therefore, of the greatest importance to Matthew.

The characteristic peculiarity of Mark as an author is particularly manifest in two points: 1. He reports rather the works than the discourses of our Saviour; 2. He gives details more minutely and graphically than Matthew and Luke; for instance, he describes the cures effected by Jesus more exactly (iv. 31, 41; vi. 5, 13; vii. 33; viii. 23). He is also more particular in stating definite numbers (v. 13, 42; vi. 7; xiv. 30), and furnishes more exact dates and times (i. 32, 35; ii. 1, 26; iv. 26, 35; vi. 2; xi. 11, 19, 20, &c.).

Most of the materials of Mark's narrative occur also in Matthew and Luke. He has, however, sections exclusively belonging to himself, viz., iii. 21, 31, sq.; vi. 17, sq.; xi. 11; xii. 28, sq. These peculiar statements of Mark have an entirely historical character: consequently we deem it unjustifiable in Strauss and De Wette to endeavour to depreciate them by calling them arbitrary additions.

We may mention respecting the conclusion of Mark's gospel (ch. xvi. 9, 20), the genuineness of which, from its omission in several of the codices, has been called in question, that Michaelis and Hug are of opinion that the addition was made by the evangelist at a later period, in a similar manner as John made an addition in ch. xxi. of his Gospel. Perhaps also an intimate friend, or an amanuensis, supplied the defect. If either of these two hypotheses is well founded, it may be understood why several codices were formerly without this conclusion, and why, nevertheless, it was found in most of them.

Among the various commentaries on the Gospel of Mark which have been published in modern times, the following deserves to be specially mentioned:—*Evangelium Marci recensuit, et cum Commentariis perpetuis edidit*, C. F. A. Fritsche, Lipsiæ, 1830. On the whole subject consult *An Introduction to the New Testament*, by Dr S. Davidson, London, 1848; also *The Origin of the Gospels*, by James Smith, Esq., F.R.S., Edinburgh, 1853. For a compendium of all critical investigations into the history contained in the gospels consult Ebrard's *Wissenschaftliche Kritik der Evangelischen Geschichte*, 2 vols. 1842.

MARKET-HARBOROUGH, a market-town of England, in the county of Leicestershire, on the left bank of the Welland, 15 miles S.S.E. of Leicester, and 83 N.W. of London. The town consists of one principal street, and several smaller ones; and it is well paved and lighted. It contains a town-hall; a handsome church of the fourteenth century, with a tower and a lofty octangular spire; places of worship for Wesleyan Methodists, Independents, and Baptists; national and British schools, a free school, &c. A silk mill and several breweries are in operation, but the inhabitants are chiefly employed in agriculture. A carpet manufactory, which formerly existed here, has been discontinued, and the wool, on being prepared here, is now sent to London to be made into carpets. Market-Harborough is mentioned in history as the head-quarters of the royalists before the battle of Naseby. It is connected with London by the North-Western and Rugby and Stamford Railways. The market-day is Tuesday; and fairs are held twice a-year. Pop. (1851) 2325.

MARKINCH, a village and parish in Fifeshire, Scotland, situated not far from the Leven, 7 miles N. of Kirkcaldy. The town contains a parish church, a Free, and a United Presbyterian church, and two schools. Coal is worked to a considerable extent in the parish; and there are also paper, woollen, linen, and flax mills, and bleachfields. The parish includes also the villages of Milton and Thornton. Markinch was formerly a residence of the Culdees. Pop. of parish (1851) 5843.

MARKLAND, JEREMIAH, one of the most learned scholars and acute critics of his age, was born in 1692 at Childwall in Lancashire, and received his education in Christ's Hospital, and at St Peter's College, Cambridge. Having taken his degree of M.A. in 1717, he soon after became a fellow and tutor in his college, a position which he subsequently resigned for that of a travelling tutor on the Continent. He became first publicly known by his *Epistola Critica*, addressed to Bishop Hare. In this he gave many proofs of extensive erudition and critical sagacity. He afterwards published an edition of the *Sylvæ* of Statius (London, 1728), and the *Supplices* (1763) and *Iphigenias* (1771) of Euripides; and he assisted Dr Taylor in his editions of Lysias and Demosthenes by the notes which he communicated to him. He also very happily elucidated some passages in the New Testament, which may be found in Mr Boyer's edition of it; and he was author of a volume of valuable remarks on the Epistles of Cicero to Brutus, and of an excellent little treatise under the title of *Quæstio Grammatica*. He died in 1776 at Milton, near Dorking in Surrey, where he had spent the greater part of a long life in the closest retirement, admired alike as a scholar and as a man.

MARLBOROUGH, a municipal and parliamentary borough and market-town of England, Wiltshire, on the left bank of the River Kennet, 13 miles N.W. of Devizes, and 75 W. by S. of London. The town consists of one main street of considerable breadth, which is crossed by other smaller ones. The houses are for the most part old and irregularly built, and many of them have curiously carved gables. The principal buildings are,—the market-house, an old building, in the upper part of which there are the council chamber, assembly rooms, and court-house; the college buildings; an old church of St Mary, built in the Norman style, with a low square tower; and an elegant modern church. There are, besides, places of worship for Wesleyan Methodists and Independents, &c., a free grammar school, national and other schools. Marlborough college was incorporated in 1845 for the education of sons of clergymen and others. A considerable commerce is carried on here, principally in coal, corn, and malt; but since the opening of the Great Western Railway the town has lost much of the importance which it derived from its situation on the high road between London and Bath. In all probability, the Roman station *Cunetio*, founded by Antoninus, was in the neighbourhood of Marlborough. Henry III. held a Parliament here, at which were enacted those laws called the Statutes of Malbridge. The borough received its first charter in 1205. It is governed by a mayor, four aldermen, and twelve councillors; and it sends two members to Parliament. Markets are held on Saturday, and fairs three times a-year. Pop. of the municipal borough (1851), 3689; of the parliamentary borough, 5135.

MARLOW, GREAT, a municipal and parliamentary borough of England, county of Buckingham, on the north bank of the Thames, 23 miles S. by E. of Aylesbury, and 31 W. by N. of London. The town consists of two principal streets at right angles to each other, and meeting in a large square, besides several smaller ones. The principal buildings are the town-hall, and the parish church, opened in 1835, and surmounted by a lofty spire. There are also places of worship for Wesleyan Methodists, Independents, Baptists, and Roman Catholics; national schools; charity schools; and other benevolent institutions. The river is here crossed by a handsome suspension bridge, with a span of 75 yards. The town possesses paper-mills and breweries; and the trade, which is considerable, consists chiefly of corn, coals, and timber. The markets have been discontinued; but large fairs are held here for horses and cattle; and there are races in August. Marlow returns two members to Parliament. Pop. of the municipal borough (1851) 4485, of the parliamentary borough (1851) 6523.

MARLOWE, CHRISTOPHER, the "Kit Marlowe" of Elizabethan wits and poets, was born at Canterbury in 1564. His birth is registered under the date of February 26, so that he was not two months older than his great contemporary in the drama, Shakspeare. Marlowe's father was a shoemaker, but he had interest enough to obtain for his son admission into King's School, Canterbury, which insured him five years' liberal education and a sum of L.4 per annum, equal to L.20 of our present money. He was entered as a pensioner of Bennet College, Cambridge, March 17, 1581, and took his degree of M.A. in 1587. Before this time Marlowe had written the first part of his tragedy of *Tamburlaine*, which was attacked in 1587 by Greene and Nash as an attempt to "outbrave better pens with the swelling bombast of blank verse." In the prologue to his play Marlowe had challenged attention to his innovation:—

> "From jigging veins of rhyming mother-wits,
> And such conceits as clownage keeps in pay,
> We'll lead you to the stately tent of war,
> Where you shall hear the Scythian Tamburlaine
> Threatening the world with high astounding terms."

Marlowe kept his word with the audience. The tragedy is full of extravagant scenes in Persia, Scythia, Morocco, &c., in which Tamburlaine is drawn in a chariot to which captive kings are harnessed, and even death is represented as afraid to face the conqueror! There is great power of expression, and some gorgeous local painting, in the drama, and its success was unprecedented. A second part was soon produced, and both were printed in 1590. Tamburlaine was followed by the *Tragical History of the Life and Death of Dr Faustus*, the *Massacre at Paris*, the *Rich Jew of Malta*, and the *Troublesome Reign and Lamentable Death of Edward the Second.* Marlowe also aided Nash in another tragedy, *Dido Queen of Carthage.* Besides his plays, all of which were highly successful, Marlowe translated part of the poem of *Hero and Leander*, from Musæus (afterwards completed by Chapman), the first book of *Lucan*, and Ovid's *Elegies*,—the last in so licentious a style that it was burned by order of the Archbishop of Canterbury. The beautiful little pastoral song, "Come live with me, and be my love," quoted in Izaak Walton's *Angler*, was also of Marlowe's composition. He had thus not only the tragic pomp and "mighty line" of the dramatic muse, but the gentler graces of the poet and lover of nature. His chief strength, however, consisted in depicting the passions —in awakening terror, pity, grief, and remorse, which, before his day, were unknown to the English stage. The latter scenes of *Faustus*, and the death-scene of *Edward II.*, are unsurpassed, even in Shakspeare, for their strong interest and sublimity. Passages of fine poetical and rhetorical beauty also relieve his darker delineations of character and daring flights of imagination; and there is little doubt that, if Marlowe had lived till his powers had been chastened and matured, Shakspeare might for once have found a rival. But Marlowe was wild and dissipated, entertaining atheistical opinions, according to his wretched associate in debauchery, Robert Greene, and numerous zealots; and he was cut off by a violent death when little more than twenty-nine years of age. One Francis Archer, a serving-man, and rival in Marlowe's "lewd love," as Meres states, had invited him to a feast at Deptford. A quarrel probably arose, for Marlowe attempted to stab his host with his dagger, while the other seized him by the wrist, and turned the dagger so that it entered Marlowe's eye, and pierced him to the brain. He died shortly afterwards, June 16, 1593.

It is usual to term Marlowe the precursor of Shakspeare. He had the priority in the use of sonorous and energetic blank verse. They were, however, of the same age; and as the great dramatist had produced at least twelve of his original plays before 1598, it is natural to infer that he had begun to write some time before Marlowe's death in 1593. He may have been engaged even as early as 1587, when *Tamburlaine* appeared, in adapting his historical dramas of *Henry VI.* and *Richard III.*, and the *Taming of the Shrew;* all which are modelled so closely on the old plays that above 2000 lines have been appropriated entire by Shakspeare. Many passages in these old plays are also found in Marlowe's *Edward II.* Stage effect was then chiefly studied; the plays were produced to be acted, not read; and so many additions were made—at least to the inferior dramas—by subsequent writers engaged by the managers, that considerable uncertainty hangs over their literary history. That Shakspeare had at first "beautified" himself by "feathers" taken from Greene or Marlowe, or both, we have shown by extracts given in the life of Greene; but his style—the garb, as it were, of his unapproachable genius—was soon distinctly formed, and the characteristics of Marlowe are also manifest in his best plays. The individuality of either cannot be mistaken; and Marlowe, however inferior, has the striking merit of originality and command of the grander elements of tragedy. (R. C—S.)

MARMANDE, a town of France, capital of an arrondissement of the same name in the department of Lot-et-Garonne, is pleasantly situated on the right bank of the Garonne, which is here crossed by a bridge with a single arch, 30 miles N.W. of Agen. Marmande has rather an antiquated appearance, many of the houses being timber-framed; but it is at the same time neat, clean, and regular, and has several fine squares and public fountains. The principal buildings are the town-hall, the court-house, and the college. The manufactures chiefly carried on here are those of hats, woollen stuffs, brandy, ropes, and leather. The Garonne is navigable as far as Marmande, and the harbour is very good. The trade is very flourishing, and consists of corn, flour, wines, tobacco, &c. Marmande is an ancient town. Having supported the cause of the Albigenses, it was taken after a disastrous siege, in 1219, by Louis VIII. and Amaury de Montfort, when most of its inhabitants were put to the sword. It was afterwards besieged in 1577 by Henri IV. Pop. (1851) 8257.

MARMONT, AUGUSTE FREDERIC LOUIS VIESSE DE, *Duc de Raguse*, Marshal of France, was born at Chatillon-sur-Seine on the 20th July 1774. At the age of fifteen he entered the army as sub-lieutenant of infantry, and in 1792 passed with the same rank into the artillery. In the following year his skill and bravery before Toulon introduced him to the notice of Bonaparte, and laid the foundation of his fortunes. He was promoted to the rank of captain in 1794, and having entered the army of the Rhine in 1795, he showed great valour at the blockade of Mayence. He then accompanied Napoleon as his principal aide-de-camp in the Italian campaign of 1796; and by his brave and skilful conduct at Lodi, Castiglione, and Saint Georges, earned his promotion to the rank of colonel, and the distinction of being sent to Paris with the captured colours. His rise became more rapid amid the toils and perils of the Egyptian expedition in 1798. For the part he acted during the capture of Malta he was created a general of brigade; and after he had distinguished himself at the battle of the Pyramids, he was appointed commander of Alexandria. He returned with Bonaparte to France in 1799, and was a zealous supporter of that general on the day of the 18th Brumaire. Shortly after this he was appointed a councillor of state and commander-in-chief of the reserve of the artillery. In this latter capacity he superintended the famous crossing of the Great St Bernard in the spring of 1800. His important share in the victory of Marengo, which was gained in the following June, raised him to the rank of a general of division. Appointed commander of the army in Dalmatia in 1806, Marmont defeated the Montenegrins, Greeks, and Russians, at Castel-Novo, and governed the duchy with so much tact and success, that he received the title of Duc de Raguse in 1808. In the following year he was summoned by Napoleon to assist in the war against Austria, and won his marshal's baton on the battle-field of Wagram. The organization of the Illyrian provinces was a result of that decisive victory, and Marmont was appointed their governor. From this office he was called in 1811 to supersede Massena in the command of the army in Portugal. There his administration was characterized by his usual ability, but not by his usual success. He was defeated by Wellington at the battle of Salamanca in 1812, and enfeebled by wounds and fatigue, he was forced to return to Paris. Summoned into action once more in 1813, Marmont fought at Lutzen, Bautzen, and Wurtzen; and while covering the retreat of the French after the disastrous battle of Leipsic, he was again wounded. In 1814, with a comparatively small force, he resisted for several hours the entrance of the allies into Paris, and not until he was nearly overborne by the numbers of the enemy did he agree to evacuate the city. Yet so much odium did he incur on account of this capitulation, that he was excepted by name from the general amnesty which Napoleon proclaimed on his return from Elba. Marmont accordingly retired to Aix-la-Chapelle during the Hundred Days, and did not return to Paris until after the battle of Waterloo. He was then nominated a major-general of the royal guard; and in 1817 he was commissioned as the king's lieutenant to allay an insurrection in Lyons. About this period he retired into the country, and devoted himself to agricultural pursuits until 1825, when he was despatched as ambassador extraordinary to congratulate Nicholas on his accession to the throne of Russia. During the Revolution he commanded, though very unwillingly, the king's troops. Having thus become the object of popular indignation, he was driven into exile on the expulsion of Charles X., and his name was struck off from the list of marshals. He latterly devoted much attention to the study of the military systems of different countries. Part of his information on this subject he published in his *Esprit des Institutions Militaires*, Paris, 1845. He died at Venice in 1852. Two volumes of his Memoirs, written by himself, were lately published in Paris.

MARMONTEL, JEAN FRANÇOIS, a celebrated French writer, was born in 1723 at the picturesque village of Bort in the Limousin, in a family little removed above the rank of peasantry. He owed the early part of his education to private charity and gratuitous public institutions. After studying at the college of the Jesuits at Clermont, he went to Toulouse, where he delivered lectures in philosophy with considerable reputation, and gained an academical prize. An accidental correspondence with Voltaire finally led to his departure for Paris in 1745, where he obtained the personal acquaintance of that highly popular writer, who at that time extended the most friendly encouragement to all young men possessed of any talents for poetry. There Marmontel commenced his career of letters by gaining a prize for a poem on a subject proposed by the French Academy, *La Gloire de Louis XIV. perpetuée dans le Roi son Successeur*. But in that age the theatre afforded the most ample field for the acquisition of wealth and eminence, and he accordingly next turned his attention to theatrical composition. His first tragedies, *Dionysius* and *Aristomenes*, obtained a flattering reception, but were soon forgotten; and his succeeding ones, *Cleopatra*, the *Heraclides*, and *Numitor*, had no success whatever. Laharpe, who was a great dramatic critic, condemns them all as bad, except the *Heraclides*, which he calls a tolerable tragedy of the second rank. In fact, Marmontel does not appear to have been endowed with any great talents for poetry or dramatic composition. His dramatic writings, however, gained for him at once both friends and fortune, and he found himself suddenly elevated from the verge of utter want, and at once plunged into all the bustling intrigue of the first literary circles, and into all the glare and dissipation of fashionable society. His time was occupied with rehearsals, love intrigues, and parties of pleasure. By addressing flattering verses to the king, and gaining the favour of other persons of influence, Marmontel obtained the situation of under-secretary of the royal buildings. This employment fixed his residence at Versailles for five years, during which time he contributed articles to the *Encyclopédie*, which were afterwards printed together in alphabetical order, under the general title of *Elements de Littérature*. He afterwards commenced the *Contes Moraux*, written originally for the *Mercure de France*, which were subsequently collected and printed by themselves. Many of these tales, on which the fame of Marmontel principally, if not solely, rests, bear reference to the original idea with which they commence, being for the most part intended to expose some absurdity or extravagance of character. In most of them he displays a very happy imitation of nature in the manners and in the language; and it is only to be regretted that he has occasionally given too high a colouring to conceptions of the most beautiful simplicity. As lively pictures of French manners, both simple and fashionable, they are admitted to be unrivalled. Having been suspected of writing a satire against some powerful nobleman, in the *Mercure*, of which he had now become the sole manager, he was, in consequence, shut up for a few days in the Bastille, and on his release deprived of his agreeable and lucrative situation. He next translated into prose the *Pharsalia* of Lucan, and added to it a supplement, in which he details the events of Cæsar's wars in Africa, and concludes with his last campaign in Spain. His next publication was a romance called *Bélisaire*, which, on its first appearance in 1768, attracted universal attention, and involved the author in a dispute with the Sorbonne, who published a censure of it, which was opposed by the arguments of Turgot, and by the epigrams and squibs of Voltaire. He some time afterwards produced his *Incas of Peru*, and, irritated as he was by the recent anathemas of the Sorbonne, his great object in this new romance was to show, that all the evils inflicted by the Spaniards on the Indians had their original in that fanaticism which he was desirous to bring into still deeper detestation. In these latter works he unluckily abandoned the simplicity which charmed so much in his *Moral Tales*, for a tone too highly rhetorical and turgid.

In 1763 Marmontel had been admitted, after considerable opposition, to the much-envied place of a member of the French Academy, and in 1783 he succeeded D'Alembert as its perpetual secretary. The situation of historiographer of France, and the chair of history in the Lyceum, which he successively obtained, fully indemnified him for the loss of the *Mercure*. He was in the full enjoyment of affluent circumstances, domestic felicity, and literary reputation, when the French Revolution suddenly changed the scene. During its alarming progress he led a retired life, and though reduced to indigent circumstances, remained secure amidst all the violent events of the period. In 1797 he was chosen a deputy to the National Assembly by the department of Eure, but he died soon afterwards, of an apoplectic attack, at his cottage near Abbeville, on the 31st December 1799.

After his death were published the *Nouveaux Contes Moraux*, 4 vols. 8vo, 1801; also a tolerable *Histoire de la Régence du Duc d'Orleans*, 2 vols. 8vo, 1805; besides his *Memoirs d'Une Pere, pour servir à l'Instruction de ses Enfants*, 4 vols. 8vo, 1804,—perhaps the most attractive and amusing of all his writings,—containing, however, among many agreeable and happy sketches, much paradox and self-contradiction; with a vast gallery of portraits of the most distinguished names of his time in France, ranging from Massillon to Mirabeau. Many of his pieces are of very doubtful morality.

MARMORA, Sea of, lies between European and Asiatic Turkey, between 40. 18. and 41. 5. N. Lat., 26. 40. and 30. 5. E. Long. It is 172 miles in length by 55 in breadth. At the east end it terminates in two long and narrow gulfs,—that of Izmid to the N., and that of Mudanieh to the S. It communicates with the Black Sea at the N.E. by the Bosporus or Straits of Constantinople, and with the Archipelago on the S.W. by the Dardanelles. The shores of the Sea of Marmora are beautiful in scenery and well cultivated; but those on the Asiatic side are bolder and more precipitous than those on the European. In some places the depth is very great; at a point 5 miles N. of Marmora Island no soundings have been obtained at 355 fathoms; and it is believed that in the centre the depth is very much greater. It is fed by several streams, of which the most important are the Karasu, Jatidji, and Chortu from Europe, and the Salataderé, Gweinimenshar, Mukhalitch, and Hyla from Asia. The navigation of the sea is safe, and not accompanied with much difficulty; and there are numerous good harbours on the northern shore and under the islands. This sea is not subject to tides; but a current runs through it from the Black Sea to the Mediterranean, varying in strength and swiftness at different seasons. The principal island, Marmora, which has given name to the sea, is celebrated for its marble quarries, from which in ancient times Cyzicus and other neighbouring cities, and in modern times Constantinople, have been supplied with building materials. The island of Marmora is occupied by a mountain range of no great height, and has a very barren appearance, although some wine is here produced. It is thinly inhabited, mostly by Greek Christians; and the town of Marmora, which stands on the S.W. coast, is chiefly built of wood. The island has a circumference of about 45 miles, and was anciently known by the names of *Proconnesus* or *Elaphonnesus*, on account probably of the deer with which it was then stocked. The other islands are,—Rabi, Liman-Pasha, Papa or Kalolimmo, and the group called Prince's Islands or Demonesi. The Sea of Marmora was called by the ancients *Propontis*, and was believed by them to lie due N. and S., so that the Dardanelles and the Bosphorus were placed on the same meridian.

MARMORICE, or Marmaras, a town of Anatolia, situated on the S.W. coast of Asia Minor, 27 miles N. of Rhodes. It is irregularly built, and the houses are mean; but it occupies a fine position at the head of a large bay. In the vicinity are the ruins of the ancient *Physeus*. The harbour is large and good, but the entrance is extremely narrow. The export trade is considerable in timber, honey, turpentine, wax, &c. At the mouth of the bay stands the cape of the same name. Lat. 36. 43. N., Long. 28. 20. E.

MARNE (anciently *Matrona*), a river of France, rising in the hills of Langres, and following a course nearly parallel to that of the Seine, flows first N.W. and then W., until it falls into that river a short distance above Paris, after a course of about 280 miles. The greater part of its course lies in the departments of Haute-Marne and Marne; but it also traverses those of Aisne, Seine-et-Marne, and Seine-et-Loire. It receives on the right the Ornain at Vitry, after a course of 48 miles; and on the left the Blaise, the Petit-Morin, and the Grand-Morin. The principal towns on the Marne are,—Langres, Chaumont, Joinville, Saint Dizier, Vitry-le-Français, Châlons, Mareuil, Epernay, Château-Thierry, Ferté-sous-Jouarre, and Meaux; and the river is navigable as far as Saint Dizier, 210 miles from its junction with the Seine. The Marne is joined to the Rhine by means of a canal, which follows for a considerable distance the course of the Ornain. It crosses the Meuse at Voide, the Moselle at Toul, and enters the Rhine at Strasbourg, its whole length being about 89 miles. Communicating with this canal another has been constructed from Vitry to Dizy, along the bank of the Marne, for 38 miles, on account of the rapid and winding character of this part of the river. There is also a third canal of 35 miles in length, which opens a communication between the Marne and the Aisne.

Marne, a department of France, situated between 48. 28. and 49. 23. N. Lat., 3. 25. and 5. E. Long., and bounded on the N. by the departments of Aisne and Ardennes, E. by those of Meuse and Haute-Marne, S. by that of Aube, and W. by those of Seine-et-Marne and Aisne. The department, which has an area of 3158 square miles, consists of a bare plain, sloping from E. to W., with a few scattered hills, which do not rise higher than 1200 feet. The soil consists of a thin layer of sand lying upon chalk, except in the W. and N.W. borders, and along the valley of the Marne, where the soil is rich and good. It is separated into two nearly equal parts by the River Marne, from which it takes its name; and is watered also by the

Aisne in the N.E.; by its tributaries the Suippe and the Vesle in the N. and N.W.; and by the Aube and the Seine in the S., the latter of which merely touches it for a very short distance. Marne enjoys a temperate climate and a pure atmosphere, although in the low and marshy tracts on the borders of the department fogs are very frequent. Cultivation is far advanced, and in a thriving condition. There are 500,000 acres of ploughed land, 193,000 of woods and forests, 189,000 of meadow land, 45,000 of vineyards, &c. Corn is grown to a considerable extent, especially oats and rye, which are more than sufficient for the supply of the wants of the department. Fruit trees are also numerous in Marne, and a great part of the department is covered with forests. But the most fruitful branch of agriculture in this district, and that on which most care is bestowed, is the cultivation of the vine, for Marne occupies a part of the old province of Champagne, so well known for the wines to which it has given name. This department produces annually about 15,400,000 gallons of wine. Many sheep are raised in Marne, and their breed has been much improved by crossing with the Merino and English breeds. The horned cattle and horses are small in size. Bees and domestic fowls are kept in great numbers in the department. The chief mineral productions are,—limestone, chalk, flint, millstones, building stone, clay of various sorts. The department is famous for the manufacture of woollen and other tissues, which centre chiefly at Rheims. The principal articles of trade are wines, together with corn, flour, brandy, hides, timber, and the produce of the manufactures. The department is crossed by the railway from Paris to Strasbourg, which enters Marne at Dormans, and leaves it at Sermaize, after a course of 68 miles. It is divided into five arrondissements, which, with their populations in 1851, are as follows:—

	Cantons.	Communes.	Population.
Châlons	5	109	52,562
Epernay	9	185	93,090
Rheims	10	183	138,031
Sainte-Menehould	3	82	36,246
Vitry-le-Français	5	135	53,373
Total	32	694	373,302

Marne, *Haute*, a department of France, bounded on the N. by the departments of Marne and Meuse, E. by that of Vosges, S. by those of Haute-Saône and Côte-d'Or, and W. by that of Aube, is situated between 47. 35. and 48. 40. N. Lat., 4. 38. and 5. 52. E. Long. The surface, which occupies an area of 2401 square miles, is for the most part hilly, and in some places mountainous. The southern part of Haute-Marne is traversed by the hills of Langres, rising to the height of 2500 feet, and the Faucilles Mountains,—the latter of which form part of a continuous chain between the Cevennes and the Vosges Mountains, and constitute the watershed between the Atlantic and the Mediterranean. The hills gradually diminish in height towards the north, where the country stretches out into beautiful valleys and extensive plains, broken here and there by hills either single or in groups. The geological character of the department is, with the exception of a single spot, of the secondary formation; and the prevailing structure is Jura limestone, with a small development of the coal measures. But notwithstanding the prevalence of mountains, and the small extent of rich soil in the department, it is well cultivated. Nearly a third of the surface is covered with forests. The principal rivers are the Marne, the Meuse, and the Aube, all of which have their sources in this department, which is also watered by several of their tributaries. The climate is healthy, and, though the cold in winter is intense among the mountains, the valleys and plains enjoy a mild and warm temperature. The amount of land producing corn in this department is 550,000 acres; vineyards, 37,500 acres; wood, 475,000 acres, &c. More corn is grown than suffices for the supply of the inhabitants: wine is also produced, but is not of great celebrity. Leguminous plants, hemp, &c., are cultivated; and a large quantity of wood is grown here for the supply of Paris. The sheep are numerous, and of a good breed, amounting to the number of 290,000; of cattle there are 90,000, not much esteemed; and of horses, 50,000. Poultry and bees are also reared; and many sorts of game abound in the department. Mining operations are carried on to a considerable extent in Haute-Marne; and the annual produce of the iron mines, for the working of which this is the first department in France, is valued at more than L.85,000. There are also quarries of good building stone, millstones, marble, &c. Iron manufacture is the chief branch of industry pursued here; and the cutlery of Langres and of Nogent is very famous. The other manufactures are,—gloves, stockings, paper, leather, beer, &c. The trade is chiefly in iron, wood, corn, wines, &c. Saint Dizier is the centre of the iron trade; and this town, along with Vitry and others, forms the principal emporium for wood. The capital of the department is Chaumont, and it is divided into three arrondissements, which, with their populations in 1851, are as follows:—

	Cantons.	Communes.	Population.
Chaumont	10	195	88,571
Langres	10	209	106,424
Vassy	8	145	73,403
Total	28	549	268,398

MARNOCH, a parish of Scotland, county of Banff, remarkable as having been the scene of one of the forced settlements which led to the disruption of the Church of Scotland in 1843, is situated on the Deveron, 9 miles S.W. of Banff; and has a population of 2994.

MARONITES, a tribe inhabiting the western declivity of Mount Libanus, figure in ecclesiastical history as a sect of Christians. By adopting the Monothelitic doctrine soon after it had been condemned in 680 by the council of Constantinople, they came to be considered a distinct religious party; and from having as their first bishop a certain monk, John Maro, they were called Maronites. Maro assumed the title of "Patriarch of Antioch," and asserted the ecclesiastical independence of the tribe. With no less intrepidity did the Maronites themselves, favoured by their native mountains, defend their freedom at first against the Greeks, and afterwards against the Saracens. At length, in 1182, they renounced the opinions of the Monothelites, and were readmitted within the pale of the Romish Church. Yet, as the terms of reconciliation were, that the religious tenets, moral precepts, and ancient rites of the country should remain unaltered, the Maronites adopted no popish opinion except the supremacy of the Roman pontiff. By this slight tie they still continue united to the Church of Rome. In return for their imperfect allegiance, the pope is obliged to defray the expenses of their public worship, and to maintain a college at Rome for the education of their priests. He has the power of sanctioning the appointment of their patriarch after he has been selected by their bishops. This dignitary resides in the monastery of Kanobin, assumes the title of Patriarch of Antioch, and by adopting the name of Peter, claims to be the successor of that apostle. Along with the bishops who compose his synod, he is bound to remain in perpetual celibacy; a law, however, which the rest of the clergy do not observe. The Maronite monks are of the Order of St Anthony, and live in convents scattered among the mountain solitudes.

Prompted no doubt by national vanity, so common among Syrians, Nairon and other Maronite doctors have essayed to prove that their tribe never entertained the Monothelitic heresy, and that it derived its name, not from John

Maro, but from Maro a monk of the fifth century. Both these statements, however, are disproved by the testimony of many unexceptionable authorities. (See Mosheim's *Ecclesiastical History*, Reid's edition.)

MAROS, or MAROSCH, a river in the Austrian empire, rises in Transylvania, in Mount Magos, a branch of the Carpathians, flows through Transylvania in a S.W. and W. direction, enters Hungary, and forms the northern boundary of the Banat, till it enters the Theiss opposite to Szegedin after a course of about 350 miles. During the earlier part of its course it is inclosed among high cliffs, but further down it flows through a wide plain. The country which it washes on either side is rich in minerals; gold and silver being found to the north, and iron, lead, and copper to the south. Its principal affluents are,—on the right side, the Aranyos; and on the left, the Nyarad, Kokel, Sebes, and Strehl. The most important towns on its banks are Arad, Karlsburg, and Szaaz; and it is navigable as far as Karlsburg.

MAROS-VASARHELY, or SZEKERLY-VASARHELY, a free town of Transylvania, capital of a circle of the same name, is situated near the Maros, 53 miles N.N.E. of Hermanstadt. The town is fortified, and occupies several small hills; the streets are wide, and the houses small, but for the most part well built. It is chiefly remarkable for its large and excellent public library of 80,000 volumes, which includes many fine editions of the ancient classics, and is kept in a handsome building. There are also here five churches, two convents, a Roman Catholic gymnasium and seminary, and a Protestant college. Maros-Vasarhely is also the seat of the Royal Table, the highest legal tribunal in Transylvania; and is in consequence a place of resort of large numbers of students and practitioners of law. In the neighbourhood is a garrisoned castle. Much tobacco is grown in the vicinity, in which the town carries on a considerable trade. Pop. 10,000.

MAROT, CLEMENT, the best French poet of his time, was born at Cahors in 1495, being the son of John Marot, valet-de-chambre to Francis I., and poet to Queen Anne of Bretagne. He enjoyed his father's place as valet-de-chambre to Francis I., and was page to Margaret of France, wife of the Duke of Alençon. In 1521 he followed that prince into Italy, and was wounded and taken prisoner at the battle of Pavia; but on his return to Paris he was accused of heresy and thrown into prison, where he wrote his *Enfer*, and revised the *Roman de la Rose*. Delivered by the protection of King Francis I., he at length retired to the court of the Queen of Navarre, then to that of the Duchess of Ferrara, and in 1536 returned to Paris; but having declared openly for the Calvinists, he was obliged to fly to Geneva, which he at length quitted for Lyons, where he renounced Calvinism; and after having taken part in the Italian campaign of 1535, under Francis I., he retired to Piedmont, and died at Turin in 1544, aged fifty. His verses are filled with natural beauties. La Fontaine acknowledged himself his disciple, and contributed greatly to restore to credit the works of this ancient poet. Marot, besides his other works, translated part of the Psalms into verse, a production which was condemned by the Sorbonne, but subsequently continued by Beza. *Michael Marot*, his son, was also the author of some verses; but they are not comparable to those of *John*, and much inferior to those of *Clement Marot*. The works of the three *Marots* were collected and printed together at the Hague in 1731, in 3 vols. 4to, and in 6 vols. 12mo.

MAROWINE, or MARONI, a river of South America, rises in the Serra Tumucucuraque, flows in a northerly direction, forming the boundary between French and Dutch Guiana, and falls into the Atlantic after a course of about 300 miles, in 5. 52. N. Lat., and 53. 50. W. Long. For about 15 miles up it is navigable for small boats; but the number of small islands, rocks, and quicksands that obstruct its course, prevent any vessel of large size from entering; and in the upper part of its course it is so much interrupted with rapids as to be totally unnavigable. It receives on the right the Rio Siburique and the Rio Waki, and on the left the Rio Tapahoni.

MARPURG, FRIEDRICH WILHELM, an eminent musical critic and writer on the theory and practice of music, was born at Seehausen, Brandenburg, in 1718. He received a good education, and early applied himself to the study of music. When about thirty years of age he was appointed to an office under government at Berlin, and from that time devoted his leisure to the writing and publishing of works on music. He published several editions of his work on the art of playing the harpsichord, and of his work on thorough-bass and composition; also several editions and a French translation of his work on fugue-writing, *Abhandlung von der Fuge*, &c.; which French translation was again published by Choron in his *Principes de Composition*, &c., 1808, and in his *Nouveau Manuel de Musique*, &c. It has been objected to Marpurg's work on fugue-writing, that he did not clearly understand the true principles of canonical imitation, nor of those most important parts of the fugue, the subject and the answer. Also, that the natural order of the objects treated of is quite inverted, double counterpoints being placed *after* fugue, and canons *after* double counterpoints. Choron rectified this confusion in his *Nouveau Manuel de Musique.* In 1758 Marpurg published a good work on the composition of vocal music, *Anleitung zur Singcomposition.* In 1763 appeared his introduction to music in general, *Anleitung zur Musik überhaupt*, &c. In 1757–74–76–79 he published four works on theoretical music and on temperament. Besides these, he published several critical and historical works relative to music, and some of his own musical compositions. He also edited two collections of pieces for the harpsichord, and a collection of fugues by celebrated German composers. He died at Berlin on 22d May 1795. (G. F. G.)

MARQUESAS, or MENDAÑA ISLANDS, a group of islands in the South Pacific Ocean, situated between 8. and 11. S. Lat., and 138. 30. and 143. W. Long. The number of the islands is twelve; and they extend to a length of 200 miles from N.W. to S.E.; being divided into two smaller groups, one lying to the N., and another to the S. The principal islands in the southern group are,—Santa Dominica or Hiwaoa, Santa Christina or Tahuata, San Pedro or Motane, and Hood's Island or Tiboa, of which the average length is about 10 miles. Of the northern group, the largest is Noukahivah, 20 miles in length and 70 in circumference; and the other principle ones are,—Uahuga or Washington Island, Uapoa or Adam's Island, Motouiti or Franklin Island, and Ohivaoa. These islands present a mountainous and rugged appearance; their coasts, which are bold and precipitous, being unprotected by any coral reefs, are exposed to the sea, which beats on them with violence; and the centre of each island is occupied by a ridge of rocky mountains, rising in the larger islands to the height of 2000 or 3000 feet. From these mountains branches stretch out, reaching down to the sea, and dividing the surface of the islands into numerous small valleys. The soil in these parts is rich, consisting of clay mixed with vegetable remains; but on the higher grounds it is thin, and produces only a coarse sort of grass. Considerable portions of the islands are covered with forests of cocoa-nut, bread-fruit, papaw, and other trees. The natural productions of this group closely resemble those of the Society Islands; but the fan palm, which is unknown in these islands, is found in the Marquesas. Cultivation is practised to a considerable extent; the principle articles of produce being cotton, sugar, tobacco, potatoes, bananas, and plantains. The inhabitants supply vessels with vegetables and live stock, in return for which they obtain muskets and ammunition for their own use and that of the neighbouring islands. The climate is warm, and the thermometer generally ranges between 64° and 80°. Abundant showers of rain fall in winter, but thunder-storms seldom take place; and sometimes for a period of ten months the islands are without rain—an event which invariably produces a famine. The trade wind from the E. blows frequently here, especially in autumn; but winds from the N. in summer, and from the N.W. in winter are very common. The inhabitants are of a copper colour, are remarkable for the symmetry of their limbs, and though not tall, their appearance is strong and healthy. While the inhabitants of each valley are governed by a single independent chief, yet the possessor of Resolution Bay, one of the best and most frequented harbours, by means of his traffic with Europeans, has acquired considerable influence over the neighbouring princes. This chief took under his protection two English missionaries, who settled here in 1835. The open practice of idolatry has been given up, yet the people still retain many of the manners and superstitions of paganism. They are, however, generally honest and well disposed to Europeans; and the ideas formerly entertained of their cruelty and cannibalism have been found by later visitors to be unfounded. These islands were first visited in 1596 by Mendaña, who discovered four of the southern group, and called them *Marquesas de Mendoza*, after Don Garcia de Mendoza, then viceroy of Peru. Hood's Island was discovered by Cook in 1776, and the others by the Americans in 1797. In 1842 these islands came under the protection of France. Pop. estimated at 20,000.

MARQUIS, or Marquess, a title of honour next in dignity to that of duke. The office of marquis is to guard the frontiers and limits of the kingdom, which were called the *marches*, from the Teutonic word *marche*, a limit, as, in particular, were the marches of Wales and Scotland whilst they continued hostile to England. The persons who had command there were called *lords marchers* or *marquesses*, whose authority was abolished by statute (27 Hen. VIII., c. 27), though the title had long before been made a mere design of honour. The first English marquis was Robert de Vere, Earl of Oxford, created Marquis of Dublin in 1385 by Richard II. This title was first known in Scotland in 1599, when the Marquises of Huntly and Hamilton were created. Since the Revolution, this title has been given as a second title on conferring a dukedom. A marquis is created by patent; his mantle is double ermine, three doublings and a half; his title is *most noble*; and his coronet has pearls and strawberry leaves intermixed round, of equal height.

MARRACCI, Ludovico, a learned Italian, who was born at Lucca in Tuscany in 1612. He applied himself principally to the study of languages, especially Greek, Hebrew, Syriac, Chaldee, and Arabic, which last he taught for some time at Rome. Pope Innocent XI. chose him as his confessor, placed great confidence in him, and would have advanced him to ecclesiastical dignities if Marracci had not opposed it. Marracci died at Rome in 1700, aged eighty-seven. The great work upon which his reputation chiefly rests is his edition of the Koran in the original Arabic, with a Latin version under the title of *Alcorani Textus universus ex correctioribus Arabum exemplaribus summa fide atque pulcherrimis characteribus descriptus*, Padua, 1698, in 2 vols. folio; the first contains the *Prodromus*, and the second the Koran, with critical and grammatical notes, which are highly esteemed. The version of the Koran by Marracci, with notes and observations by himself and others, and a synopsis of Mohammedan religion, by way of introduction, was published by Heineccius at Leipzig, 1721, in 8vo. Marracci had also a hand in the *Biblia Sacra Arabica Sacræ Congregationis de Propaganda Fide jussu edita, ad usum Ecclesiarum Orientalium*, Rome, 1671, in 3 vols. folio.

MARRAST, Armand, a French journalist, and one of the chief authors of the republican constitution of 1848, was born in the south of France in 1802. His career as a political writer began at Paris in 1827, and he soon became distinguished as a defender of the practical school of philosophy as opposed to the eclecticism of Cousin. In 1830 he established the newspaper *La Tribune*, which during several years was the acknowledged organ of the ultra-Liberals. For some fierce invectives in this periodical against the government Marrast was at different times prosecuted; and for a pamphlet entitled *Vingt Jours de Secret* he was compelled to flee to England. In 1836, when Carrel was slain in a duel, Marrast succeeded him as chief editor of *Le National*, and speedily converted that organ of moderate and philosophical Republicanism into a vehicle of vigorous but scurrilous tirade. By his bold and persistent attacks upon the government and the court, he was a chief instrument in accelerating the Revolution of 1848. Accordingly, he acted a prominent part in the new government, became president of the National Assembly, and was re-elected to the same office at the end of several successive months. As rapid, however, in his fall as in his rise, Marrast was soon forced to flee from the vengeance of the Red Republicans, and living in retirement, he was almost forgotten, when his death, in March 1852, introduced his name once more to the public.

MARRIAGE. See Husband and Wife.

MARRUCINI, a people of Central Italy, inhabited a narrow strip of land extending along the banks of the River Aternus (*Pescara*), from the Adriatic to the Apennines, and bounded on the S. by the territory of the Frentani. Their country, on account of its eastern exposure, was more fertile than the neighbouring districts. Teate (*Chieti*), situated on the Aternus, was their most important city. The Marrucini were of Sabine origin. They were an independent people, although they almost invariably appear in history as allies of the neighbouring tribes of the Marsi and Peligni. Along with these they became confederates of the Romans in 304 B.C., and revolted at the commencement of the Social War. Their district was included in the Fourth Region of Augustus.

MARRYAT, Frederick, *Captain*, R.N., C.B. and F.R.S., was born in London, on the 10th of January, 1792. He was the second son of Joseph Marryat, Esq. of Wimbledon House, Surrey, M.P. for Sandwich, a considerable West India merchant, and chairman of Lloyd's, who traced his descent from a family of French refugees. He was educated in London, and entered the navy in 1806 as midshipman on board the "Impérieuse," a frigate of 44 guns, commanded by Lord Cochrane, under whom he served till 18th October 1809, taking gallant part in the daring exploits of that celebrated officer. During this time he was in nearly fifty engagements of more or less importance, in the Mediterranean and on the coast of France. Once, in boarding a vessel in the bay of Arcupon, he was knocked down by the fall of the officer in command, close behind whom he was entering, trampled upon in the rush of his own party, and left for dead. In 1808 and 1809 he took part in the reduction of the castle of Mongat, the defence of the castle of Trinidad, and the attack on the French fleet in Basque Roads. For the gallantry and ability displayed in these dangerous services, he received honourable mention in Lord Cochrane's despatches. Four times he jumped overboard to rescue shipmates, on one of which occasions he narrowly escaped being devoured by a shark; and once his skill and intrepidity saved his ship. He was lieutenant in 1812, and appointed to "L'Espiègle," in the West

Indies, whence he removed, in January 1814, to the "Newcastle," 58 guns, Captain Lord George Stuart, which was despatched to the American coast, and cut out four vessels at New Orleans. In 1815 he acquired the rank of commander, had the "Beacon" sloop off St Helena, then the "Rosario," 18 guns, in which he brought home despatches announcing the death of Napoleon. After being some time employed in the preventive service, in which he effected thirteen seizures, he was appointed to the "Larne," 18 guns, in March 1823, and sailed to the East Indies, where, till 1825, he was fully employed as senior officer of the naval forces. He led the attack on Rangoon in 1824, and was twice thanked by the governor-general of India for his services in the Burmese war. He was also warmly recommended by Sir Archibald Campbell, the commander-in-chief, from whom he received three letters of thanks. In February 1825 he accompanied Sir Robert Sale in the successful expedition to reduce the territory of Bassein, and returning in April, was promoted to the command of the "Tees," which he brought home to England. In June 1825 he received the decoration of C.B., and a medal from the Humane Society for saving so many lives. From November 1828 to November 1830, he commanded the "Ariadne" in the Channel service. It was at this time, in 1829, that he began his literary career; encouraged by the reception of his *Frank Mildmay*, he produced in rapid succession his well-known novels,—*The King's Own*, *Peter Simple*, *Jacob Faithful*, *Japhet in Search of a Father*, *Newton Forster*, *Midshipman Easy*, *The Pacha of many Tales*, *The Poacher*, *The Phantom Ship*, *Snarly Yow*, *Olla Podrida*, *Poor Jack*, *Masterman Ready*, *Percival Keene*, *Monsieur Violet*, *Settlers in Canada*, *The Mission*, *The Privateersman*, *Valérie*. The most of these are sea-novels, of very unequal merit, but all lively, and abounding in adventure. His descriptions of any other life than life on board ship, and any other characters than sailors, are not brilliant nor accurate, though always lively and spirited; but in his own walk he is unrivalled, and in this his best works are perhaps *Peter Simple* and *Poor Jack*. His *Code of Signals for the use of Vessels employed in the Merchant Service*, published in 1837, was adopted by our government, and is now in general use by our own and foreign navies. For this service he twice received the thanks of the Shipowners' Society; and the work being translated into French in 1840, and adopted, he received from Louis Philippe the gold cross of the Legion of Honour. His *Diary in America*, published in 1839, in two series of three volumes each, is an amusing and clever production, written, however, with little aim beyond amusement, and full of satirical exaggeration. It gave great offence in the United States. He died on the 2d of August 1848, at Langham in Norfolk, after having for a year or two been obliged to desist from all literary and professional exertion by the bursting of several blood-vessels. By his marriage with Catharine, daughter of Sir Stephen Shairp, formerly *chargé d'affaires* at St Petersburg, he had six children. His eldest son, a lieutenant in the navy, perished in 1847 in the "Avenger" steamer, on the coast of Africa. (W. H. C.)

MARS, the Roman god of war, was originally called *Mavors* or *Mavers*, and was identical with the Sabine and Oscan deity Mamers. Among the Romans he came gradually to be viewed in three different characters, and to receive different names corresponding to these characters. He appears to have been regarded originally as the father of Romulus, and accordingly was considered one of the tutelary divinities of Rome. In this character he was called *Quirinus*, a name derived from the Quirinal Hill, on which his ancient temple stood. But, as the founder and patron of Rome, Mars was naturally supposed to preside over agriculture, the favourite calling of the primitive Romans. He was therefore worshipped as a rustic deity, under the title of *Silvanus*. Another honourable vocation, however, in ancient Rome was the art of warfare. For the same reason, therefore, that Mars was held to be the god of agriculture was he supposed to be the god of war. In this last character he was worshipped under the name of *Gradivus* by priests called Salii. Mars was generally painted as an armed warrior of a fierce aspect, riding in a chariot, and brandishing a spear. His shield (*ancile*) is said to have fallen from heaven in the reign of Numa, and was carefully preserved as the symbol of the perpetuity of the Roman power. To lessen the chances of its being stolen, it was placed among eleven other shields exactly like it. At the ancient temple of Mars, near Reate (*Rieti*), the responses of the god were communicated by the mouth of his sacred bird the woodpecker (*picus*). He was also worshipped with great honours at Tuder (*Todi*), in a sanctuary still seen in ruins. Of the numerous temples dedicated to him at Rome, the most famous was that of Mars Ultor, built by Augustus in the Forum Augusti. The quadrupeds sacred to Mars and most acceptable to him in sacrifice, were the horse and the wolf. The name of his wife was said to be Nerio or Neriene. At an early period he was identified with the Greek god Ares. The month of March and the Campus Martius were named after Mars.

MARSAIS, CESAR CHESNEAU DU. See DUMARSAIS.

MARSALA (the ancient *Lilybœum*), a seaport of Sicily, in the province of Trapani, is situated on the low promontory of Cape Boeo, on the W. of the island, 18 miles S.S.W. of Trapani. The town is of a square form, and surrounded by old fortifications, which, though at present neglected, might easily be rendered capable of defence. The ancient harbour was good, but is now filled up, and the present one is about a mile S. of the town. Marsala is traversed by a straight and broad street, called the Cassaro, in which stands a large cathedral, with sixteen handsome Corinthian columns of marble. The town has sixteen other churches, many convents, three abbeys, a gymnasium, seminary, hospital, &c. Among the curiosities of the place may be mentioned an old castle, a church with a tower which perceptibly vibrates by the ringing of the bell, and a few remains of aqueducts and tombs of ancient date. The harbour was so highly esteemed by the Saracens as to have received from them the name of *Marsa Alla* (the Harbour of God). In modern times Marsala derives its chief importance from its trade in the wine grown in the neighbourhood, which is much prized. The quantity produced in the neighbourhood is calculated to amount to 30,000 pipes, of which about two-thirds are exported principally to England, the United States, and the West Indies. Small quantities of corn, cattle, oil, &c., are also exported from Marsala. Pop. about 21,000.

MARSDEN, WILLIAM, an eminent oriental scholar, was the son of a merchant in Dublin, and was born in 1754. After studying at Trinity College in that city, he obtained an appointment in the civil service of the East India Company, and set sail for Bencoolen, Sumatra, in 1771. There he soon rose to the office of principal secretary to the government, and was at the same time intent on acquiring that intimacy with the Malay language, and that knowledge of the country, which were afterwards the sources of his literary reputation. Returning to England in 1779 with a pension, he retired into literary seclusion; and in 1782 produced *The History of Sumatra*. Marsden was appointed in 1795 second secretary, and in course of time first secretary, to the Admiralty. In 1807 he retired again into private life, and devoting himself to study, published in 1812 his *Grammar* and *Dictionary* of the Malay language, and in 1817 his translation of the *Travels of Marco Polo*. A pension of L.1500, which he had received on his retirement from office, he voluntarily resigned in 1831 for the behoof of the public. In 1834 he presented his rich collection of oriental coins to the British Museum, and his library of books and oriental MSS. to King's College. He died of apoplexy in October 1836. Marsden's other works are,—*Numismata Orientalia* (Eastern Coins), 4to, London, 1823–25; *Catalogue of Dictionaries, Vocabularies, Grammars, and Alphabets*, 4to, London, 1796; and several papers touching the language, manners, and antiquities of the East, in the *Philosophical Transactions* and the *Archæologia*.

MARSEILLE, a town of France, capital of the department of Bouches-du-Rhone, is situated on the Mediterranean, 30 miles W.N.W. of Toulon, and 475 S.S.E. of Paris. This city was founded about the year 600 B.C. by a colony of Greeks from Phocæa in Ionia, and was called by them *Massalia*, which was afterwards changed by the Romans into *Massilia*, from whence was derived its modern name. (See MASSILIA.)

After the fall of the Roman Empire, Marseille was at different times under the power of the Visigoths, Ostrogoths, and Franks. In the year 720 the greater part of the town was taken and sacked by the Saracens; but the upper city held out until Charles Martel and his brother Childebrand came to the rescue and expelled the Saracens. After this period Marseille continued to increase in wealth and prosperity, though much harassed and threatened by pirates, especially during the reign of Louis le Débonnaire in the ninth century. Up to the time of William I., Viscount of Marseille, this city had preserved a republican form of government; but under that prince and his successors, till the twelfth century, the government was monarchical, though this change exercised no adverse influence on the progress of the arts, industry, and commerce of Marseille. For some time after the restoration of the republican constitution, Marseille formed one of a confederacy of similar small states, including those of Arles, Grasse, &c., and after a struggle for six years against the Counts of Provence, was finally obliged, in 1243, to recognise their authority. Soon afterwards, however, Marseille was involved in a war with Charles of Anjou, brother of Louis IX., which ended in its falling into the hands of that prince. Under the House of Anjou, Marseille continued until the year 1482, when Charles du Maine, the heir of the line of Anjou, bequeathed Marseille to Louis XI., with a stipulation that the time-honoured liberties of the city should be respected. In the year 1524 Marseille was besieged by the imperialists under the Constable de Bourbon, but the inhabitants made a desperate resistance, and succeeded in repelling their adversaries. Marseille was made by Louis XIII. a station of the French navy, and provided with a dockyard and arsenal; and the good effects of this were seen in the clearing the Mediterranean of the pirates which infested it. In the reign of Louis XIV. a sedition broke out here, of which the ringleader was Noiselles; but the "Great Monarch" having made his appearance in 1660, quelled the sedition, and deprived the city of its peculiar privileges, erecting at the same time the citadel of St Nicolas. In 1720 and 1721 Marseille suffered from a fearful visitation of the plague, which, although it had frequently made its appearance previously, had never been so destructive as on this occasion, when it carried off between 50,000 and 60,000 victims. Marseille hailed with joy the beginning of the first French Revolution, but the event did not correspond to the hopes entertained at the outset, and the commerce of Marseille was almost ruined in the commotions of that unhappy period. After the Restoration, however, the city recovered its former commercial importance, and is now daily increasing in wealth and magnificence.

The situation of Marseille is not only very convenient for commerce and navigation, but is extremely beautiful and picturesque. It is built on the slope of the hills which surround the excellent harbour in a semicircular form. The town consists of two distinct parts, an old and a new; the former, which occupies the site of the ancient *Massilia*, is situated on uneven ground to the N. of the harbour, and is irregularly and ill built, with narrow and dirty streets. The new town, on the other hand, consists of broad and straight streets, as well as splendid and elegant squares, which rival in magnificence those of Paris. The division between the old and new town is marked by a public promenade called the "Cours," lined with trees, and adorned with numerous fountains, and which, along with the streets of Aix and Rome, forms a thoroughfare extending in a straight line through the city, from the triumphal arch at the northern extremity, to an obelisk which stands near the gate by which the road from Rome enters Marseille. Another favourite promenade is the Rue de la Cannebière, a broad street extending from the Cours to the harbour, and commanding a view of the shipping. The walls which formerly inclosed Marseille have been converted into boulevards; and beyond these the town has extended, and is still rapidly extending itself, in all directions. On a hill to the S. stands the fort of Notre Dame de la Garde; and the entrance of the harbour, formerly closed during the night by a chain, and hence called "La Chaine," is protected by the Fort St Jean on the N., and St Nicolas on the S. The approach is still further guarded by the fortified island of If, which has long served as a state prison, as well as by the islands of Pomegue and Ratoneau, which are also fortified. The harbour of Marseille, which was in ancient times called *Lacydon*, is of a rectangular shape, and is about 1020 yards in length by 327 in breadth. It is secure and convenient, and surrounded by a number of excellent quays, which are always thronged with a busy crowd of men of all nations. Although the harbour can accommodate 1200 vessels, it has been found insufficient for the numbers of those frequenting it, and a new harbour has been accordingly constructed, called La Joliette, opposite to Fort St Nicolas. The neighbourhood of Marseille is extremely dry and barren; and although there are numerous *bastides* or country houses in the vicinity, the only attraction which these possess is the view of the sea, to which Marseille owes not only its wealth, but a great part of its beauty. The public buildings of Marseille are not so numerous as might be expected; and the view of the city from an eminence is remarkably destitute of spires, domes, and other indications of large and handsome buildings. The cathedral, which is called the "Major," or the church of St Victor, is of very great antiquity, but is by no means an elegant or imposing structure, and its castellated towers give it the appearance rather of a fortress than of a place of worship.

The Hôtel de Ville stands on the northern side of the harbour, and is a rather heavy building, said to be the work of the celebrated Puget, but which was in all probability executed by some inferior hand. One of the finest buildings in Marseille is the Hôtel de la Prefecture. The only others that deserve notice are the new market-house, the theatre, resembling the Odeon at Paris, and the Palais de Justice. In the neighbourhood is the chapel of Notre Dame de la Garde, which contains an ancient olive-wood statue of the Virgin, held in the highest veneration by sailors and fishermen, and a modern one of silver; besides many votive pictures. The church of St Madeleine, also in the suburbs, is an elegant building, and has two light steeples and a fine front. The town contains altogether about twenty Roman Catholic churches, two Greek ones, one Protestant church, and a synagogue. There is a museum and picture gallery, in the former of which are to be seen a few remains of the ancient city of Massilia, which are not of much interest, and do not ascend to a higher antiquity than the time of Julius Cæsar. The number of pictures in the gallery is about 150, and some of them are very good, though they are not hung in a favourable light. The public library of Marseille consists of about 80,000 printed volumes and 1300 MSS. Marseille has a royal college, occupying a building which was formerly a Bernardine convent, and attended by 300 or 400 students; a royal society of science, literature, and art; an observatory, with schools of navigation, geometry, &c., a good museum of natural history, and a botanic garden. There are at Marseille numerous charitable institutions. The Hôtel Dieu, founded in 1188, is one of the oldest hospitals in France, and is capable of accommodating 750 patients. The Hôpital de la Charité, for the aged, orphans, &c., contains generally from 600 to 680 persons. Situated to the N. of the city is the lazaretto, one of the most perfect establishments of the sort in Europe. This institution is rendered necessary by the frequency with which Marseille has been visited by the plague. The town also possesses public baths. There are published at Marseille three newspapers and several literary journals. The city has a tribunal of primary instance and one of commerce, a chamber of commerce, a council of *prud'hommes*, a *syndicat maritime*, and an *hôtel des monnaies*. Although Marseille is not famous for its manufactures, yet its industry in this department is considerable, and there are many important manufacturing establishments. In former times Marseille was much celebrated for the manufacture of coral into various articles; but this has of late much fallen off, and is now carried on to a greater extent at Genoa, Leghorn, and Naples. Soap-making is largely carried on, and affords employment to about 700 hands. Next in extent to the soap-works of Marseille are the refineries of sugar, sulphur, wax, and borax; the manufactures of steam-engines and machinery; the tanneries, which, however, have rather fallen off of late; the manufacture of hats, of which there are produced from 40,000 to 65,000 annually; the making of china, glass, bricks, &c. The Marseillais are also employed to a considerable extent in the salting of meat and fish, and in the pickling and preserving of various sorts of fruits. The fish and the flower markets are in general well stocked, and present a very animated appearance. An aqueduct has been recently constructed, with great labour and expense, for conveying the water of the Durance to the town. This gigantic work, one of the greatest of its kind in modern times, is remarkable for the bold and skilful engineering with which it has been executed; it is about 60 miles in length, and is carried through 15 miles of tunnels. Marseille, however, is chiefly remarkable as a commercial city, in which respect it is second to none in France, being the great emporium for all the southern parts of the kingdom. Its position is in many respects most favourable for trade, being situated on the shores of the Mediterranean, and having Spain on the right, Italy on the left, and Africa in front; while at the same time it communicates with the centre of France by the large and navigable River Rhone. The exports include all sorts of articles of home produce, such as silk, linen, and woollen stuffs; wines, brandies, &c.; oil, soap, refined sugar, perfumery, stationery, and gloves. Among the imports may be noticed sugar, coffee, &c., from the colonies; corn from Africa and the Black Sea; manufactured goods from England; cotton, hides, wool, tallow, timber, &c. The great advance of Marseille in trade dates from the French conquest of Algiers in 1830, since which time this town has had almost a monopoly of the trade with that country. It is also the chief station for the steam-packets on the line of communication with Malta, Alexandria, and Constantinople. The number of vessels belonging to the port in 1851 was 804, the tonnage 92,237; and in 1855 the number was 913, and the tonnage 130,860. The number of vessels that entered in that year was 5016; that left, 4433; and in 1856 the aggregate number entered and left was 10,183. The total value of the articles imported in 1853 has been computed to amount to L.8,000,000; and the exports are believed to be about equal in value. In 1855 the value of the imports was above L.11,000,000. The quantity of duties collected at Marseille in 1851 was L.1,227,000, being greater than the amount collected at any other port of France. The people of Marseille still preserve many traits of the ancient Greek character, and are noted for their superstitious observance of rites and ceremonies. This may be remarked in the votive offerings with which the chapels are hung round, and in the numerous religious processions, in which the gaiety as well as the superstition of the people find expression.

The Marseillais do not regard themselves as of the same country with the rest of the French, and manifest the same contempt for strangers that was characteristic of the ancient nations. The dialect which is spoken by the greater part of the inhabitants of Marseille is Provençal, which is made up of a mixture of Greek, Latin, Catalan, and French, with a great number of words whose origin can be traced to none of these languages. Marseille is distinguished as having given birth to many famous personages; among whom, in ancient times, the most illustrious was Pytheas the navigator: and in modern times, Puget the artist and architect, born in 1622; Mascaron the preacher, born in 1634; and Peysonnel the antiquary, born in 1700,—may be noticed. Pop. (1851) 185,082.

MARSH, Dr Herbert, Bishop of Peterborough, was born in London in 1757. After receiving his education and gaining a fellowship at St John's College, Cambridge, he removed to Germany in 1783, and resided for several years at Göttingen. In a short time he had become sufficiently intimate with the language of that country to publish several German tracts in defence of the policy of Great Britain touching the continental wars. So successful were these pamphlets in effecting the purpose at which they aimed, that Marsh, on the recommendation of Mr Pitt, was rewarded with a pension, and was now started on the open road to preferment. On the invasion of Germany by the French he returned to England. Created D.D. by royal mandate in 1806, Marsh was appointed in 1807 Lady Margaret's professor of divinity at Cambridge. In teaching from this chair he abandoned the custom of lecturing in Latin followed by his predecessors, and lectured only in English. He was promoted to the see of Llandaff in 1816, but was translated to that of Peterborough in 1819. He died in 1839. Varied as well as profound, the learning of Bishop Marsh comprised an intimacy with theology, politics, and Greek, Latin, German, and oriental literature. He was the first who imported into this country the biblical criticism of Germany. In defence of his own church, he was an uncompromising foe of Calvinism on the one hand and Popery on the other. His translation of *Michaelis's Introduction to the New Testament* was reckoned a work of great value.

The chief of his other works are,—*The Authenticity of the Five Books of Moses considered*, 4to, Cambridge, 1792; *The History of the Politics of Great Britain and France, from the time of the Conference at Pilnitz to the Declaration of War against Great Britain*, 2 vols, 8vo, London, 1800; *Lectures on the Criticism and Interpretation of the Bible, with two Preliminary Lectures on Theological Study and Theological Arrangement*, 8vo, London, 1838; *Lectures on the Authenticity and Credibility of the New Testament, and on the Authority of the Old Testament*, a new edition, 8vo, London, 1840; and *The National Religion the Foundation of National Education*, 8vo, London, 1811.

MARSHAL, or Mareschal (*marescallus*), primarily denotes an officer who had the charge or the command of horses, and from the importance of such an office, ultimately became invested with great military authority. The title of Marshal of England, formerly passed by grant from the king, has been hereditary in the family of the Dukes of Norfolk since 1672. The earliest marshals on record are those of William the Conqueror, viz., William Fitz-Osborne and Roger de Montgomery. The earl marshal holds the eighth rank among the great officers of state in England, and exercises the same authority over the Court of Chivalry which the constable and marshal together formerly possessed. In Scotland the office of earl marshal has never been out of the family of Keith. The *Marshal of the King's Household* hears and determines pleas of the Crown; and the *Marshal of the King's Bench* has the custody of the King's Bench Prison, Southwark, or of the *Marshalsea*, as it is thence called. The *Marshal of France* is the highest military rank in the French army, as that of *Field-Marshal* is in our own.

MARSHAM, Sir John, a learned chronologist, the son of an alderman of London, was born in that city in 1602. From Westminster School he passed in 1619 to St John's College, Oxford, where he was chosen Master of Arts in 1625. During the two following years he travelled in France, Italy, and Germany, and then repaired to London to study common law in the Middle Temple. In 1629 he went to Paris in the suite of Sir Thomas Edmunds, ambassador extraordinary. His studies, thus interrupted, were resumed on his return; and in 1637 he was appointed one of the six clerks of Chancery. Adhering to the cause of the royalists during the civil war, Marsham was deprived of his office and of part of his estate, and on the complete defeat of his party, was fain to compound for the remnant of his property, and to devote himself to literature. He was member for Rochester in the Parliament that recalled Charles II.; and immediately after the Restoration in 1660 he was restored to his clerkship in Chancery, and was created a knight. Three years afterwards a baronetcy was added to his honours. He died at Bushy Hall, Hertfordshire, in May 1685. Sir John Marsham was an eminent scholar in languages, history, and chronology. His works were, *Diatriba Chronologica*, 4to, London, 1649; and *Chronicus Canon Ægyptiacus Hebraicus et Græcus*, folio, London, 1672, Leipsic, 1676, and Franeker, 1696. The former is an attempt to elucidate the chronology of the Old Testament; the latter, besides comprising a great part of the former, has an ingenious disquisition on the Egyptian dynasties.

MARSHFIELD, a market-town of England, county of Gloucester, 13 miles E. of Bristol. The principal street is about a mile long; and the town consists chiefly of old buildings. There is a parish church, places of worship for Independents and Unitarians, an endowed school, and several alms-houses. A considerable trade is carried on in malt. The market-day is Tuesday; and there are two annual fairs. Pop. 1648.

MARSHMAN, Joshua, D.D., an eminent missionary, was born at Westbury Leigh in Wiltshire in 1767, and was sent to the East Indies in 1799 by the Baptist Missionary Society, to join the Serampore Brethren, as Dr Carey and his colleagues were styled. On reaching the sphere of his labours, Marshman, in addition to his more special duties, engaged in the study of the Bengalee, Sanscrit, and Chinese languages, which, after great perseverance, he succeeded in mastering. He afterwards translated into Chinese the book of Genesis, the four Gospels, and the Epistles of Paul to the Romans and the Corinthians. In 1809 he published a *Dissertation on the Characters and Sounds of the Chinese Language;* in 1811 he produced *The Works of Confucius, containing the Original Text, with a Translation;* and in 1814 appeared his *Clavis Sinica*. He also wrote *Elements of Chinese Grammar, with a Preliminary Dissertation on the Characters and Colloquial Medium of the Chinese;*—all printed at Serampore. As the result of his Sanscrit and Bengalee studies, he engaged with Dr Carey in 1815 in writing a Sanscrit grammar, and in 1825 a Bengalee and English dictionary. Owing to some painful misunderstanding which arose between the Serampore Brethren and the committee of the Baptist Missionary Society in 1815, and which resulted in their acting for some time as separate bodies, Dr Marshman was induced in 1826 to visit England, where the causes of difference were subjected to strict scrutiny. The famous John Foster, with whom Dr Marshman resided, shook off his langour for a time in order to get to the bottom of this matter; and after the most ample opportunity of acquainting himself with all the circumstances of the case, and while admitting that Marshman's conduct was regulated too much on the principle of silent pertinacity and cautious "management," he nevertheless unhesitatingly alleged, "I believe there is not in Christendom a man more highly and uniformly conscientious, a man more anxiously and scrupulously solicitous to do right in all things." He returned to Serampore in 1829, but did not enjoy the satisfaction of witnessing the re-union of the mission there with the parent society, concluded in London a few days before his death, which took place on the 5th of December 1837. After the conversion of Rammohun Roy to Christianity, Dr Marshman replied to a work of the rajah's assailing the miracles of Christ, entitled *The Precepts of Jesus the Guide to Peace*, in a series of articles in the *Friend of India*, subsequently collected and published under the title of *A Defence of the Deity and Atonement of Jesus Christ, in Reply to Rammohun Roy of Calcutta*, London, 1822; to which the rajah published a reply in the second London edition of his book in 1824.

MARSI, an ancient tribe of Central Italy, inhabited the district around the Lake Fucinus (*Lago di Celano*). They were of Sabine origin, and accordingly they were closely related by descent, as well as by common political interests, with their neighbours, the Vestini, the Peligni, and the Marrucini. Indeed, their name seems to indicate that they were the parent stock of the last tribe. Their only important town was *Marrubium*, still seen in ruins on the E. shore of Lago di Celano. At what period the Marsians became allies of the Romans is unknown; but we find that they revolted in 308 B.C., and leagued themselves with the Samnites. After they had been subdued, they again, in 301 B.C., shook off the alliance of Rome, and not until they had ceded part of their territory could they conciliate their former ally. From this period they continued to fight submissively under the Roman banners, until the Italians demanded in 91 B.C. a share in the privileges of the citizens of Rome. The Marsians then took so prominent a position among the malcontents, that the struggle which ensued, though generally known as the Social War, was frequently styled the Marsic War. When a series of defeats, or the concessions of their enemies, had won the rest of the allies to submission, the Marsians kept the field alone, and although they were often defeated, only laid down their arms in 87 B.C., when they had attained the object for which they had taken them up. Thus they became amalgamated with the other Italian tribes, and lost their national individuality.

Inhabiting a mountainous district, the Marsians were simple and temperate in their habits, but hardy, brave, and stubborn in action. So marked was their valour, that at one time there was a current saying that Rome had achieved no triumph *over* the Marsi or *without* the Marsi. The ancient Marsians were noted for their ability to tame serpents and to heal their bites; and it is rather remarkable that the jugglers who at present amuse the populace of Rome and Naples by handling these reptiles, are natives of the vicinity of the Lago di Celano.

MARSIGLI, Luigi Ferdinando, Count, an Italian geographer and naturalist, was descended of an ancient and noble family, and born at Bologna on the 10th of July 1658. He studied under Borelli and Malpighi, and acquired an extensive knowledge of the art of war and of fortification. He subsequently served under the Emperor Leopold II. against the Turks, by whom he was taken prisoner in 1683, but ransomed after a year's captivity. In the war of the Spanish succession, Marsigli, then advanced to the rank of marshal, being in the fortress of Brisack, which surrendered to the Duke of Burgundy in 1703, when the place was deemed capable of holding out much longer, was stripped of all his commissions, and had his sword broken over him. Marsigli now turned his attention exclusively to science, in which he had made great progress during his military career. In 1712 he presented the senate of Bologna with his astronomical and chemical instruments and apparatus, his plans of fortifications, models of machinery, &c., laying thereby the foundation of the Institute of the Arts and Sciences of Bologna. He also established a printing-house, furnished it with the best types for Latin, Greek, Hebrew, and Arabic; and in 1728 presented it to the Dominicans at Bologna, upon condition of their printing all the writings of the Institute at prime cost. This was called the Printing-House of St Thomas Aquinas. His writings on philosophical subjects are numerous and valuable. The most remarkable are,—*Osservazioni intornò al Bosforo Tracio overo Canale di Constantinopoli*, Rome, 1681, in folio; *Dissertatio de Generatione Fungorum*, ibid. 1714, in folio, rare and curious; *Briève Ristretto del Saggio Fisico intorno alla Storia del Mare*, Venice, 1711, in folio, translated into French by Leclerc under the title of *Histoire Physique de la Mer*, Amsterdam, 1725, in folio; *Danubius Panonico-Mysicus Observationibus Geographicis, Astronomicis, Hydrographicis, Historicis, Physicis, perlustratus*, Hague, 1726, in 6 vols. large folio; *Etat Militaire de l'Empire Ottoman, de son Progrès, et de sa Décadence*, in French and Italian, Amsterdam and Hague, 1732, in folio, with 44 plates, and a map of the Ottoman Empire by Abubekir Effendi, with the names in the Turkish language. Marsigli died at Bologna on the 1st of November 1730.

MARSIVAN, or Marsovan, a village of Asiatic Turkey, pashalic of Sivas, situated on a wide plain, 24 miles W.N.W. of Amasia. It contains about 6000 houses, and has several mosques and fountains. Some manufactures of cotton fabrics are carried on here. Marsivan is believed to occupy the site of the ancient *Phagemon*.

MARSTON, John, a dramatist and satiric poet of the Elizabethan age, is supposed to have been born about 1575. The facts of his biography are very few and very uncertain. Anthony Wood supposes, but for no satisfactory reasons, that he was educated at Corpus Christi College, Oxford. As early as 1601 he was of sufficient importance as a writer to be satirized, under the name of Demetrius, in Ben Jonson's *Poetaster*. This enmity between the two authors seems to have afterwards subsided, for in 1605 Marston dedicated to Jonson, with expressions of affection and esteem, *The Malcontent*, a play which he had altered from Webster. In the same year also he was assisted by Jonson and Chapman in the composition of *Eastward Hoe*. For some reflections against the Scots in this comedy the authors were thrown into prison by the king, and were only released after they had lain for some time in the horrifying expectation of having their ears cut off and their noses slit. Shortly after this the intimacy between Marston and Jonson appears to have been once more interrupted. The former, in his preface to his *Sophonisba*, published in 1606, hints at the plagiarisms from Roman authors that are found in the *Catiline* and *Sejanus* of the latter; while Jonson, during his sojourn in 1619 with Drummond of Hawthornden, refers to an enmity between him and Marston that had subsisted for a considerable time. The life of Marston can be traced as far down as 1633. With little of the imitative and inventive genius of the dramatist, Marston had much of the spirited vigour and pungent wit of the satirist. In the *Scourge of Villainy*, the best of his satires, he is lofty and intrepid in his censure of vice, but is often carried by his vehement invective to the very verge of coarseness and indecency. In addition to those already mentioned, his other works are,—*The Metamorphosis of Pigmalion*, a satire, 16mo, London, 1598; *Antonio and Mellida*, a tragedy, 4to, 1602; *Antonio's Revenge*, a tragedy, 4to, 1602; *The Dutch Courtesan*, a comedy, 4to, 1605; *Parasitaster*, a comedy, 4to, 1606; *What You Will*, a comedy, 4to, 1607; *The Insatiate Countess*, a tragedy, 4to, 1613. Marston's miscellaneous poems were edited by Mr Bowle, 12mo, London, 1764.

MARTA, or Martha Santa, a town of New Granada, South America, capital of a province of the same name in the department of Magdalena. It stands on the Caribbean Sea, 105 miles N.E. of Cartagena, in Lat. 11. 15. N., Long. 74. 18. W. It was founded in 1525, and was constituted an episcopal city four years afterwards. It was repeatedly sacked by pirates during the sixteenth and seventeenth centuries; and in 1672 was completely pillaged by a French and an English vessel. Latterly, however, it rose into considerable importance as a commercial city, and enjoyed the almost exclusive privilege of importing goods for the capital of the country. It suffered much from the attacks of the Indians during the revolutionary war, and does not appear to have regained its former importance. The harbour is one of the best on this coast, having sufficient depth of water and good holding ground. It is defended by a castle on the summit of an isolated and almost perpendicular rock, and by several batteries. The cathedral is a very conspicuous object; but neither its architecture nor its internal decorations are worthy of notice. The climate is salubrious, although in summer the heat is very great; and the town is abundantly supplied with water. Pop. about 8000

MARTABAN. See Pegu.

MARTIALIS, M. Valerius, the famous Latin epigrammatist, was born on the 1st of March A.D. 43 at Bilbilis (*Bambola*) in Spain. He was educated at Calagurris (*Calahorra*), and repaired to Rome in 66. The fame of his epigrams soon spread through the city, and had even passed into Gaul, Germany, and the uncivilized countries of the north. Patronized successively by the Emperors Titus and Domitian, Martial was raised to the Equestrian Order and to the tribuneship, and received the honourable privilege called *jus trium liberoram*. He seems to have acquired a fair fortune, for he talks with the complacency of a proprietor about his mansion in the city and his country house at Nomentum. Disheartened probably by the small encouragement extended to literature under Trajan, Martial left Rome in 100, after a sojourn of 35 years. On his departure, his friend the younger Pliny, in return for a complimentary address. gave him a sum of money to defray his travelling expenses. This fact, by an inference not quite legitimate, has been made the ground of a common opinion that the epigrammatist at this time was in straitened circumstances. From Rome Martial immediately repaired to his birthplace, and there he seems to have married Claudia Marcella, a lady whose graces and accomplishments he celebrated with affectionate pride. He passed his latter years on the property of his wife, near the banks of his native Salo (*Xalon*). The time of his death is unknown, but it was probably after A.D. 104.

The pieces of Martial generally known as his *Epigrams* amount to 1500, divided into fourteen books. Of these books the two last, called respectively *Xenia* and *Apophoreta*, consist entirely of distichs descriptive of the small articles of luxury and ornament which the Romans usually presented to their friends on festal seasons. In addition to these epigrams, Martial wrote what is commonly known as

Liber de Spectaculis, a work of thirty-three pieces on the shows exhibited by Titus and Domitian. It is doubtful whether all the poems of Martial are extant, and whether all those now ascribed to him are genuine. The best editions of Martial are those of Scriverius, Leyden, 12mo, 1619; Amsterdam, 12mo, 1621, and 16mo, 1629; Lemaire, 3 vols. 8vo, Paris, 1825; and Sschneidewinn, 2 vols. 8vo, Grem. 1842. Martial was translated into French verse by Marolles, 4to, Paris, 1675. His select pieces have been translated into English metre, and published in London, by May, 1629; Fletcher, 1656; Hughes, 1737; Hay, 1754; Wright, 1763; Rogers, 1782; and Elphinstone, 1783,—the dullest of them all. There is an old MS. of Martial in the Advocates' Library, Edinburgh.

In the hands of Martial the epigram first became a short poem abounding with ingenious and pointed thoughts, and compressing in its conclusion all the pith of its preceding parts. To him, therefore, this species of poetry owes its present form. Amid much of the forced ingenuity and over-laboured expression that always attend epigrammatic composition, Martial displays a refined felicity of diction, a fertile fancy, and a wit equally delicate and pungent. He also shows at times a love and talent for the description of rural scenes. More interesting, however, to the modern student is the full and minute delineation which he gives of the public and private customs of his age. Yet all these estimable qualities are neutralized to a considerable extent by the shameless obscenity that abounds in his writings, and the mean-spirited adulation which he lavishes upon Domitian. These open offences against morality and self-respect, after every possible palliation has been pleaded for them, must always affect the character of Martial both as a man and as an author.

MARTIGUES, a town of France, department of Bouches-du-Rhone, and arrondissement of Aix, is situated on the channel between the lagoon of Berre and the Mediterranean, 15 miles N.W. of Marseille. It consists of three distinct parts,—the town proper, called the Isle, on an island in the channel, and the suburbs of Jonquières and Ferrières, the former on the south and the latter on the north bank. Its situation has acquired it the designation of the Venice of Provence. The town is generally well and regularly built, and has several handsome buildings. It carries on an active coasting trade. Pop. 8000, most of whom are engaged in fishing.

MARTIN, Louis-Aimé, a distinguished French writer of the present century, was born at Lyons in 1779. After having received an excellent education in his native city, he set out for Paris at the age of twenty, and became connected with the *Journal des Débats*, for which he contributed articles on scientific subjects. By his *Lettres à Sophie sur la Physique, la Chimie, et l'Histoire Naturelle,* published in 1810, he gained for himself an honourable position among the rising literary men of his time, and which was more than confirmed a short time afterwards by his lectures at the *Athénée* on the literary history of France. He was appointed to a secretaryship under the Chamber of Deputies; and delivered a course of lectures during the same year to the École Polytechnique on the History of France, which he followed up in 1830 by a course on the History of Germany. Martin became early imbued with the somewhat extravagant ideas of progress then current in France, and devoted himself with praiseworthy energy to the realization of his cherished schemes for the regeneration of human society. He advanced new systems of instruction, projected communal libraries, and took a principal share in founding the Panthéon Littéraire, a collection of the *chefs-d'œuvre* of all nations, which, by popularizing instruction, were designed to improve the character, and increase the happiness of men. He published his views on this subject in his *Plan d'Une Bibliothèque Universelle; Etudes des Livres qui peuvent servir à l'Histoire Philosophique de Genre Humain*, Paris, 1837. But Martin soon became alive to the fact, that his plans for securing the welfare of humanity were not quite so enlightened or profound as he had been led to believe, and that the perfecting of mechanical contrivances, and the construction of railways, while ministering to the material comforts of a people, tend, besides, to augment their wants, and increase their desire for gratifying them. Accordingly, in his work *De l'Education des Mères de Famille*, dedicated to M. Lamartine, which received the prize from the French Academy in 1835, he endeavoured to conduct men to a higher order of truths, and pointed them to religion as the true source of earthly happiness. His ideas on religion, however, did not meet with the approval of the Roman Catholic church, and his book for the edification of the mothers of France was placed on the *Index.* A warm admirer of Bernardin de Saint Pierre, Aimé Martin married the widow of that eminent writer, collected his writings, and vindicated his memory from the unjust attacks to which it had been exposed. He died at Saint Germain-en-Laye on the 18th November 1847, aged sixty-two; and his friend M. de Lamartine pronounced an eloquent funeral oration over his tomb.

In addition to his other works, Aimé Martin published excellent editions of the works of Molière and of Racine, with notes; of the *Maximes* of La Rochefoucauld, with a critique; of the *Œuvres Philosophiques* of Descartes; and of Fénélon's *Traité de l'Existence de Dieu,* with additions.

MARTIN, *Benjamin*, an eminent artist and mathematician, was born in 1704. After publishing a variety of ingenious treatises, and particularly a scientific magazine under his own name, and carrying on for many years an extensive trade as an optician and globe-maker in Fleet Street, the growing infirmities of age compelled him to withdraw from the active duties of business. Trusting too fatally to what he thought the integrity of others, he unfortunately (though with a capital more than sufficient to pay all his debts) became bankrupt. The unhappy old man, overpowered by this unexpected blow, attempted in a moment of desperation to destroy himself; and the wound he gave himself, though not immediately mortal, hastened his death, which happened on the 9th February 1782, in his seventy-eighth year. He had a valuable collection of fossils and curiosities of almost every kind, which, after his death, were disposed of by auction. His principal publications are,—

The Philosophic Grammar, being a View of the Present State of Experimental Physiology, or Natural Philosophy, 1735, 8vo; *A New, Complete, and Universal System or Body of Decimal Arithmetic,* 1735, 8vo; *The Young Student's Memorial Book, or Patent Library,* 1735, 8vo; *Description and Use of both the Globes, the Armillary Sphere, and Orrery,* 1736, in 2 vols. 8vo; *Memoirs of the Academy of Paris,* 1740, in 5 vols.; *System of the Newtonian Philosophy,* 1759, in 3 vols.; *New Elements of Optics,* 1759; *Mathematical Institutions, viz., Arithmetic, Algebra, Geometry, Trigonometry, and Fluxions,* 1759; *Natural History of England, with a Map of each County,* 1759, in 2 vols.; *Philology and Philosophical Geography,* 1759; *Mathematical Institutions,* 1764, in 2 vols.; *Lives of Philosophers, their Inventions, &c.,* 1764; *Introduction to the Newtonian Philosophy,* 1765; *Institutions of Astronomical Calculations,* in 2 parts, 1765; *Description and Use of the Air-Pump,* 1766; *Description of the Torricellian Barometer,* 1766; *Appendix to the Description and Use of the Globes,* 1766; *Philosophia Britannica,* 1778, in 3 vols.; *Gentleman and Lady's Philosophy,* in 3 vols.; *Miscellaneous Correspondence,* in 4 vols.; *System of Philology; Philosophical Geography; Magazine,* complete in 14 vols.; *Principles of Pump-work; Theory of the Hydrometer;* and *Doctrine of Logarithms.*

MARTIN, *David*, an eminent Protestant divine, born at Revel in 1639. After the revocation of the Edict of Nantes he went to Holland, and became pastor and professor of theology and philosophy, where he remained till his death in 1721. He is best known by his editions of the Scriptures. The most popular of his biblical works is his *History of the Old and New Testament*, 2 vols. folio, Amst. 1700, known as "Mortier's Bible."

Martin, *John*, one of the most celebrated painters of the present century, was born at Haydon Bridge, near Hexham, Northumberland, on the 19th of July 1789. Having early expressed a desire to become a painter, his father decided upon apprenticing him to a coach-builder in Newcastle, to learn herald-painting, whither his family had removed. In consequence of a quarrel with his master, who does not seem to have treated young Martin very handsomely, the aspiring artist, eager "to practise," as he says himself, "the higher mysteries of the art," after having his original indentures cancelled, was placed under Bonifacio Musso, an Italian painter of considerable merit, and father of the eminent enamel-painter Charles Musso or Muss. Martin removed to London with his Italian master in September 1806, where he was engaged in painting on china and glass, "by which," he says, "and making water-colour drawings, and teaching, I supported myself; in fact, mine was a struggling artist's life when I married, which I did at nineteen." During his two years' residence in London, Martin applied himself with indefatigable industry during his leisure hours to the study of perspective and architecture, labouring till two or three o'clock in the morning in the depth of winter;" and stimulated now by new responsibilities, he resolved to put forth a bold effort, and paint a large picture. This resolution he carried into effect; and after a month's application, he gave to the world in 1812 his first work, "Sadok in search of the Waters of Oblivion," which was admitted into the exhibition of the Royal Academy, and subsequently purchased for fifty guineas. His next works were the "Paradise," which obtained a place in the great room of the Academy, and the "Expulsion," which was sent to the British Institution. His next paintings, "Clytiæ" and "Joshua," were placed by the Academy in an ante-room, a circumstance which so offended Martin, that he removed his name from their list of candidates for membership, and by the laws of the academicians was thus rendered incapable of afterwards receiving any distinction at their hands. But the ultimate success of his "Joshua" amply compensated for the neglect shown to it by the Academy. This striking production was afterwards exhibited at the British Institution, and carried off the prize of the year. "The success of my 'Joshua,'" says Martin, "opened a new era to me." The attention excited by his next picture, the "Fall of Babylon," which appeared in 1819, was second only to that of the "Belshazzar." "Macbeth," one of his most successful landscapes, appeared the following year; and in 1821 he completed his elaborate picture of "Belshazzar's Feast," on which he had wrought an entire year, and which was awarded the premium of L.200 by the British Institution. Martin had now attained a wide celebrity, and thus his most famous painting met at once with vehement opposition and unhesitating praise. His paintings were engraved, and found an extensive sale all over the kingdom. During all this storm of excitement this adventurous artist held on his way, and produced his "Destruction of Herculaneum" in 1822; the "Seventh Plague" and "Paphian Bower" in 1823; the "Creation" in 1824; the "Deluge" in 1826; and the "Fall of Nineveh" in 1828—one of the most popular of all Martin's works. The cycle of his great works was now completed, and while his later pictures met with admirers, the enthusiasm awakened by his earlier efforts did not reappear. His hands were now full with the illustrations of Milton, which he drew on plates, and for which he received 2000 guineas. Martin was now much before the public in connection with various plans for improving the city of London, an object which he had deeply at heart, and for which he laboured with much energy during the last twenty years of his life. Occupied with these projects, Martin laid aside his pencil for some time, and on resuming it, found that his power had greatly left him. Yet his "sublime style" was continued during the rest of his life. He produced "The Death of Moses" and "The Death of Jacob" in 1838; "The Eve of the Deluge" and "The Assuaging of the Waters" in 1840; "The Celestial City and River of Bliss" and "Pandemonium" in 1841; "The Flight into Egypt" in 1842; "Christ Stilling the Tempest" and "Canute the Great rebuking his Courtiers" in 1843; "Morning and Evening" in 1844; "The Judgment of Adam and Eve" and "The Fall of Adam" in 1845; "Evening—Coming Storm" in 1846; "Arthur and Ægle in the Happy Valley" in 1849; "The Last Man" in 1850; "Valley of the Thames, viewed from Richmond Hill," in 1851; "Scene in a Forest—Twilight," 1852. Martin had been employed for the last four years on three great pictures illustrative of the last judgment, entitled "The Judgment," "The Day of Wrath," and "The Plains of Heaven," at which he laboured until within a few weeks of his death, and which he left unfinished. Having been attacked with a stroke of paralysis, he repaired to Douglas, Isle of Man, in quest of health, where he died on the 9th of February 1854. (See Martin's Autobiographic Notes in the *Athenæum* of February 25, 1854.)

Martin during his day had no rival in point of popularity, except Turner the great master of landscape. Martin's brother artists not unfrequently found much in his style to censure. Leslie, who was one of his warmest friends, while admiring the original power of Martin, found frequent occasion to dissent emphatically from his mode of treatment. His merits and defects were alike unquestionable; and it was the bold originality of the man that provoked so much criticism. In his expression of material grandeur he addressed the eye rather than the mind; in his delineations of the awful and the terrible in nature his imagination outran his judgment. Yet he triumphantly succeeded in ravishing the senses of the multitude, and in dazzling the eyes even of sagacious men. Whether it was by an illusory trick rather than by a stroke of genius, by bold theatrical display rather than by the chastened power of an exalted imagination, that Martin captivated the eyes of his admirers, he at all events acquired a very great popularity, and so long as his manner was new, he was enthusiastically applauded as a man of pre-eminent genius. He was certainly gifted with a power to fascinate, but familiarity was calculated to break the spell.

Martin, *Louis-Claude de Saint*, called the "Unknown Philosopher," was born at Amboise, of a noble family, on the 18th of January 1743. Originally designed for the magistracy, he preferred the profession of arms; and at the age of twenty-two became an officer in the regiment of Foix, and was made a chevalier of St Louis in 1789. His taste for spiritualism induced him to enter the secret school of Martinez Pasqualis, where he had an opportunity of becoming acquainted with the theurgical operations practised at that institution. Though originally disposed to believe in that system, he nevertheless ultimately abandoned its mystical labyrinths for the pursuit of a purer spiritualism. While not embracing all the ideas of J. J. Rousseau, he yet displayed a profound sympathy for that philosopher. But his unhesitating admiration was reserved for the Teutonic philosopher Jacob Boehm, whose singular writings—many of which Saint Martin translated—stamp with a character of originality the illuminism of the early part of the seventeenth century. The Revolution, in its various phases, found Saint Martin always the same. He saw in it the designs of Providence, and recognised equally a predestined instrument in the remarkable man who ultimately put an end to its excesses. Appointed in 1794 to give lectures at the normal schools, Saint Martin publicly refuted with great success the materialism of Garat, professor of mental philosophy at that institution. His life, nevertheless, remained obscure, being known only to a narrow circle of distinguished friends, who knew how to appreciate him. It was with one of those, Count Lenoir Laroche, at Aunay, that he died of an attack of apoplexy on the 13th of October 1803.

A Life of the "Unknown Philosopher" was written by M. Gence in 1824. The sect called "Martinists" at the epoch of the Revolution did not receive their name from Saint Martin, as many have supposed, but from his master, Martinez Pasqualis. (*Dictionnaire des Sciences Philosophiques.*)

The principal works of this eminent mystic are,—*Des Erreurs et de la Verité*, 1775; *Tableau Naturel des Rapports qui Existent entre Dieu, l'Homme, et l'Univers*, 1782; *Lettre à un Ami sur la Revolution Française*, 1795; *Eclair sur l'Association Humaine*, 1797; *Quelles sont les Institutions les plus propres à Fonder la Morale d'un Peuple*, 1798; *L'Homme de Desir*, 1790; *Ecce Homo*, 1792; *Le Nouvel Homme*, 1792; *De l'Esprit des Choses*, 1800; *Discours en Reponse au Citoyen Garat*, 1802; *Le Ministre de l'Homme Esprit*, 1802. Also, two volumes of posthumous works, entitled *Quelle est la Manière de Rappeler à la Raison les Nations, tant Sauvages que Policées, qui sont Livrées à l'Erreur ou aux Superstitions de tout Genre?* 1807.

MARTIN, ST, one of the West India Islands, belonging partly to France and partly to Spain. (See GUADALOUPE.)

MARTINI, GIOVANNI BATTISTA, the most learned musician of the eighteenth century, was born at Bologna on the 25th of April 1706. His father, Antonio Maria Martini, a violinist, taught him very early the elements of music, and to play on the violin. He was then instructed in singing and harpischord-playing by Padre Predieri, and afterwards in counterpoint by Antonio Riccieri. After the requisite religious studies and training, he took holy orders as a Franciscan on the 11th September 1722. He cultivated the theory and practice of music so successfully, that although only nineteen years old, he was appointed in 1725 chapel-master of the church of St Francis at Bologna. In the composition of religious music he received instructions from Jacopo Perti. He studied mathematics under Zanotti, and devoted much of his time to the reading of ancient and modern works on music. He was constantly collecting such works, and at last was in possession of the most extensive musical library that had ever been formed.[1] The books and MSS. of the Cavaliere Ercole Bottrigari, a distinguished amateur, formed a part of Padre Martini's library; and it has been stated repeatedly that they were left to him as a legacy by Bottrigari,—a statement utterly disproved by dates, for Bottrigari died in 1612, and Martini was born in 1706. At Bologna Padre Martini opened a school of musical composition, in which several celebrated musicians were trained. Among his best pupils were Padre Paolucci, Padre Sabbatini, Rutini, Zanotti, Sarti, the Abate Ottani, and the Abate Stanislao Mattei. Padre Martini always declared his preference for the ancient Roman school of musical composition. His school became so celebrated throughout Europe, that the best musicians consulted him on doubtful points. Burney, in his musical tour through France and Italy in 1770, gives a most pleasing account of the amiable manners and character of Padre Martini. After long and patient suffering under a complication of diseases, Martini expired at Bologna on the 4th of August 1784. The greater part of his compositions for the church are unpublished. In 1734 he published some church music for four voices, and in 1736 sonatas for organ and harpsichord. Of his sonatas for organ and harpsichord, published in 1747, Clementi has given several in the second volume of his *Practical Harmony*. In 1763 Martini published chamber duetts for different voices. His most important works are his *Storia della Musica*, of which three volumes only appeared, and his *Saggio di Contrappunto*. The former exhibits prodigious reading and industry, but is written in a dry style, and is overloaded with matter belonging to the regions of conjecture. The fourth volume, which he left incomplete, and which has not been published, was to contain inquiries regarding the music of the middle ages, down to the eleventh century. At the beginning and end of each chapter of his musical history Martini gives enigmatical canons, some of which are exceedingly puzzling. Cherubini resolved the whole of them. His *Saggio di Contrappunto* is a very learned and valuable work, in two volumes 4to, and contains numerous examples by the best masters, with excellent explanatory notes. It treats chiefly of the tonalities of the plain-chant, and of counterpoints constructed upon them. Besides several controversial works published by Martini, he drew up a *Dictionary of Ancient Musical Terms*, which was published in the second volume of the collection of G. B. Doni's works, in three volumes folio. He published also a work on *The Theory of Numbers as applied to Music*; and a paper on the "Use of Geometrical Progression in Music." (G. F. G.)

MARTINIQUE, one of the French West India Islands, the most northern of the Windward group, lies between Lat. 14. 24. and 14. 53. N., and Long. 60. 50. and 61. 18. W., about 20 miles N. of St Lucia. It is very irregular in form, and is about 50 miles in length from N.W. to S.E., by about 15 in mean breadth. Area 382 square miles. The surface is uneven and mountainous, and has several extinct volcanoes. The highest point in the island, Mont Pelee, rises to the height of 4450 feet. Extensive masses of volcanic rocks cover the interior, and extend from the mountains to the shore, where they form lofty cliffs. Between the volcanic rocks broad irregular valleys of great fertility occur. Those on the W. side, called *Basse-Terre*, are more extensive and fertile than those on the E. side, called *Cabes-Terre*. The valleys are watered by a great number of small streams. About two-fifths of the surface are under cultivation, the remainder being covered with trees, or occupied by naked rocks. The principal productions are sugar, coffee, cocoa, &c. The exports for the year ending 31st December 1851 were,—sugar, 51,610,160 lb.; coffee, 224,590 lb.; cocoa, 318,595 lb.; cassia, 360,669 lb.; logwood, 110,682 lb.; molasses, 7427 gallons; rum, 234,297 gallons. In 1854 the total value of exports from this island to France was L.552,000; of imports from France L.816,000. The coast being indented by numerous bays and inlets, affords many good harbours. There are two towns on the island, Port Royal and St Pierre; the former the capital, but the latter the more populous, and the centre of commerce. For administrative purposes it is divided into two arrondissements, fourteen cantons, and twenty-six communes; and is under a governor, with a privy council of seven members, and a colonial council of thirty members. Martinique, the native name of which is *Madiana*, was discovered by the Spaniards in 1493, and colonized by the French in 1635. It was taken by the English in 1762, and again in 1794 and 1809; and was finally given up to France in 1814. Pop. (1854) 123,701.

MARTINUS, Bishop of Tours, a celebrated ecclesiastic, was born of heathen parents at Sabaria (*Steinam-Anger*) in Pannonia about 316. After receiving his education at Pavia, he entered the army at the age of sixteen, and served successively under Constantius and Julian. While stationed in Gaul he was admitted into the Christian church by baptism, and abandoning soon afterwards the profession of arms, he was consecrated to the priesthood by Hilarius of Poitiers. Having returned to Pannonia, he converted his mother, and became noted for his fearless opposition to the Arians, who were then on the ascendant. Directing his steps once more towards Gaul, he founded on his way a monastery at Milan, and sojourned in its retirement for some time. On his arrival at Poitiers about 360, he built another monastery on a piece of ground which had been presented to him by Hilarius. In 371, so high had his alleged miraculous power, his fanatical piety, and his sordid austerities raised him in the estimation of the populace, that the inhabitants of Tours forced him to become their bishop. Finding, however, that the miserable cell in which he had taken up his abode was not a sufficient protection against the flocks of his admiring visitors, he built the monastery of Marmontier, on the banks of the Loire, and there he secluded himself for the rest of his life. Martinus died in his eightieth year, near the close of the fourth century. For many years afterwards his memory was held in the greatest veneration, not only in France, but in other countries of Europe. An invocation of St Martin was universally regarded a sovereign remedy for all diseases, whether bodily, mental, or moral. His Life by Sulpicius Severus, one of his disciples, is still extant. The *Confessio Fidei de Trinitate*, usually attributed to Martinus, is of doubtful authenticity.

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[1] See the article BURNEY, in which Martini's books and MSS. are noticed as they remained in 1819.

MARTOS, a town of Spain, province of Jaen, stands on the slope of a steep hill, which is surmounted by a ruined castle, 16 miles W.S.W. of Jaen. The streets are steep, narrow, crooked, and unpaved; but there are some handsome public buildings, including several churches, chapels, and convents, town-house, prison, hospital, theatre, and orphan asylum. It is a place of resort on account of its mineral waters; and it has two bathing establishments. Pop. about 10,000.

MARTOS, IVAN PETROVICH, an eminent sculptor, sometimes called "The Canova of Russia," was born about 1755 at Itchnia in Little Russia. He removed at an early age to St Petersburg; and in course of time his works had attained so high a position that he was sent as a pensioner to Rome, where he sojourned for three years, zealously studying his art, and cultivating an intimacy with the famous painters Raphael Mengs and Pompeo Batoni. On his return to his native country, he was employed by government in adorning the principal cities of Russia with monuments of eminent men. Accordingly, he executed a colossal group in bronze of Minin and Pozkarski at Moscow, and erected a monument to the Emperor Alexander at Taganrog, to the Duke of Richelieu at Odessa, to Lomonozov at Archangel, and to Potemkin at Kherson. Martos was for many years director of the Academy of Fine Arts in St Petersburg. He died in that city in April 1835. The chief excellence in the works of Martos is the simple and natural drapery of his figures. He also surpassed his contemporaries in subjects of bas-relief.

MARTYN, HENRY, a celebrated missionary, was born in 1781 at Truro in Cornwall, where his father, a man of singular piety and intelligence, was a labourer in the mines of Gwennap, and subsequently a merchant's clerk in Truro. He received his education at the grammar school of his native town, and at St John's College, Cambridge, which he entered in 1797, and pursued his studies so successfully, that in January 1801 he obtained the highest academical honour of senior wrangler, and in 1802 was chosen a fellow of his college, besides gaining the highest prize of the university for Latin prose composition. During this brilliant career the mind of Martyn became seriously occupied with the truths of religion, induced to some extent, it is believed, by the death of his father, which produced a very serious impression on the ardent and thoughtful student. These impressions were fostered by the intimacy which Martyn had formed with the celebrated university preacher, the Rev. Charles Simeon. Notwithstanding the bright prospects of advancement which his talents opened up to him, he resolved to devote the energies of his life to the work of a Christian missionary; and accordingly, after some preliminary preparation, he in 1805 left the banks of the Cam for the shores of India as a chaplain in the East India Company's service. He commenced his labours among the Europeans at Dinapore, and soon found himself capable of extending his labours, by conducting divine worship among the natives in their own vernacular language, and by establishing schools for their instruction. It was not till 1809, however, that his regular public ministrations among the heathen commenced. In the spring of that year he was removed to Cawnpore, where he was exposed to great privation, having to preach in the open air, under a burning Indian sun. Martyn, nevertheless, zealously pursued his noble work among the hundreds of heathen mendicants who crowded around him. During his residence at Dinapore he had been engaged in revising the sheets of his Hindustanee version of the New Testament, and in superintending the Persian translation executed by Sabat; and having now perfected himself in the latter language, he resolved to extend his missionary labours to Persia. He accordingly took up his residence at Shirauz, where he occupied himself in revising, with the aid of the learned natives, his Persian and Arabic translations of the New Testament, and in conducting religious conversations and discussions among the moollahs and soofis, many of whom were greatly impressed by him. "Henry Martyn," said a Persian moollah, "was never beat in an argument. He was a good man; a man of God." Here, in addition to his New Testament, he executed a Persian translation of the Psalms,—"a sweet employment," as he says in a letter, "which caused six weary moons that waxed and waned since its commencement to pass unnoticed." Having made an unsuccessful journey to Tabriz to present the shah with his translation of the New Testament, he was seized with fever, which so thoroughly prostrated his energies, that after a temporary recovery, he found it necessary to seek a change of climate. He set out for Constantinople, and after a hurried march of great suffering he got as far as Tokat in Asia Minor, where he was compelled to stop from utter prostration, and falling either a sacrifice to the plague which then raged there, or sinking under his previous disorder, he died on the 16th October 1812, in his thirty-second year. The news of his death was received in England with deep regret. In addition to his valuable labours as a translator, by which he placed portions of the Scriptures within the reach of all who could read over one-fourth of the habitable globe, he was instrumental in leading a considerable number of Hindus and Mohammedans to profess their adherence to the Christian faith. From one who had accomplished so much in a great cause in the very dawn of his career, it was not singular that much should have been expected from him ere he was called upon to retire from the field. Yet during his brief career he earned for himself a foremost place among modern missionaries; and the name of Henry Martyn will be held in honour as long as noble Christian heroism is admired among men. (See *Memoir of the Rev. Henry Martyn*, by the Rev. John Sargent, London, 1819.)

MARTYR (μάρτυρ) signifies properly *a witness*, and is applied in the New Testament—1. To judicial witnesses (Matt. xviii. 16; xxvi. 65, &c.). 2. To one who has testified, or can testify, to the truth of what he has seen, heard, or known. This is a frequent sense in the New Testament, as in Luke xxiv. 48; Acts i. 8, 22, &c. 3. The meaning of the word which has now become the most usual is that in which it occurs most rarely in the Scripture, *i.e.*, one who by his death bears witness to the truth. In this sense we only find it in Acts xxii. 20; Rev. ii. 13; xvii. 6. This now exclusive sense of the word was brought into general use by the early ecclesiastical writers, who applied it to every one who suffered in the Christian cause. (See Suicer, *Thesaurus Eccles.* sub voc.) Stephen was in this sense the first martyr; and the spiritual honours of his death tended in no small degree to raise to the most extravagant estimation, in the early church, the value of the testimony of blood. Eventually a martyr's death was supposed, on the alleged authority of the under-named texts, to cancel all the sins of the past life (Luke xii. 50; Mark x. 39); to supply the place of baptism (Matt. x. 39); and at once to secure admittance to the presence of the Lord in Paradise (Matt. v. 10–12). In imitation of the family custom of annually commemorating at the grave the death of deceased members, the churches celebrated the deaths of their martyrs by prayer at their graves, and by love-feasts. From this high estimation of the martyrs, Christians were sometimes led to deliver themselves up voluntarily to the public authorities—thus justifying the charge of fanaticism brought against them by the heathen. For the most part, however, this practice was discountenanced, the words of Christ himself being brought against it; Matt. x. 23. (See Gieseler, *Eccles. Hist.* i., 109, 110; Neander's *Church Hist.* i., p. 463.)

MARTYR, PETER, a famous reformer, whose family name was Vermigli, was born at Florence in 1500. At the age of sixteen he became an Augustine monk of the monastery of Fiesole, and was afterwards employed in teaching philosophy, theology, and Greek at Padua, and in preaching in the principal cities of Italy. He was led to renounce the Romish creed through a perusal of the writings of Luther and Zwingle, and was accordingly, in 1542, forced to flee before the persecuting zeal of his brother-priests. After sojourning successively at Zurich and Basle he became professor of divinity at Strasburg. Invited to England in 1549 by Archbishop Cranmer, he was appointed in the same year to a theological chair at Oxford. The accession of Mary, however, in 1553, obliged him to resign his appointment, and to return to his former chair at Strasburg. Soon after his departure from England, the remains of his deceased wife were disinterred at Oxford, and buried under a dunghill. In 1556 Martyr was translated from Strasburg to a theological professorship at Zurich. He died there in 1562. Of Peter Martyr's numerous theological treatises, his *Loci Communes*, published at Geneva in 1624, is best known.

MARTYROLOGY, a catalogue or list of martyrs, including the history of their lives and sufferings for the sake of religion. The Martyrology of Eusebius of Cæsarea was the most celebrated in the ancient church. It was translated into Latin by St Jerome, but it is not now extant. That attributed to the venerable Bede, in the eighth century, is of very doubtful authority, there being found in it the names of several saints who did not live till after his time. The ninth century was very fertile in martyrologies; for then appeared that of Florus, subdeacon of the church at Lyons, who, however, only filled up the chasms in Bede. This was published about the year 830, and was followed by that of Waldenburtus, monk of the diocese of Trèves, written in verse about the year 844; and this again by that of Usuard, a French monk, which was written by the command of Charles the Bald in 875, and is the martyrology now ordinarily used in the Roman Catholic church. That of Rabanus Maurus, written about the year 845, is an improvement on Bede and Florus; that of Notker, monk of St Gall, was written about the year 894. The martyrology of Addo, monk of Ferrières, in the diocese of Trèves, afterwards archbishop of Vienne, was compiled from the Roman in 858. According to Du Sollier, the martyrology of St Jerome is the great Roman martyrology; from this was made the little Roman one printed by Rosweyd; and of this little Roman martyrology was formed that of Bede, afterwards augmented by Florus. The martyrology of Nevelon, monk of Corbie, written about the year 1089, is little more than an abridgement of that of Addo. Father Kircher also makes mention of a Coptic martyrology preserved by the Maronites at Rome. Middleton, in his *Letter from Rome*, has satisfactorily shown that many of the accounts in the martyrologies are pure fabrications; and that persons who never existed, inanimate objects, and heathen deities, have been canonized as martyrs and saints. We have likewise Fox's *Book of Martyrs*, containing valuable accounts of the sufferings of the Reformers. (For further information on this subject consult Ruinart's *Acta Martyrum;* Dodwell's *Dissertationes Cyprianicæ;* Dr Middleton's *Free Inquiry, &c.*, and Maitland's *Church in the Catacombs.*)

MARVELL, ANDREW, an English patriot of the seventeenth century, enjoys the distinction of having been the friend of Milton, the last member of Parliament who received wages from his constituents, and one of the most acute, learned, and witty controversialists and satirists of his age. He was born at Winestead in Holderness, county of York, on the 2d of March 1621. His father, a clergyman, afterwards removed to Hull, as lecturer in Trinity church, and master of the grammar school of that town. The death of the elder Marvell took place in 1640, under circumstances too remarkable to be ever forgotten in the Yorkshire calendar. He had agreed to cross the Humber with a young couple whom he was to marry at Barrow in Lincolnshire. The day was stormy, and the minister, though persuaded to share the danger of the passage, was so strongly impressed with a presentiment it would prove fatal, that, on entering the boat, he threw his cane ashore, exclaiming, "Ho, for heaven!" His fears were realized—the boat went down, and all on board perished. The parents of the affianced lady, it is said, adopted young Marvell as their son, and enabled him to travel abroad. He had when very young been entered of Trinity College, Cambridge, but was seduced away from the university by some Jesuit emissaries. His father found him in London and took him back to college, and Marvell ever afterwards was a firm friend of Protestant freedom and enlightened toleration. From a letter of Milton's to Secretary Bradshaw (discovered so late as 1826 in the State Paper Office), it appears that Marvell spent four years abroad in Holland, France, Italy, and Spain, and on his return was engaged in giving instruction in the languages to a daughter of Lord Fairfax. He had also been engaged by Cromwell to superintend the education of a Mr Dutton in Eton. In 1654 Marvell writes to Milton from Eton, describing his presentation of a copy of the *Defensio Secunda*, sent by Milton to Bradshaw (not to Cromwell, as Birch and Dr Symmons suppose). In 1657 Marvell was associated with Milton in the Latin secretaryship, the salary of each being the same, namely, L.200 per annum. In 1660 the citizens of Hull elected Marvell their representative in Parliament, and in December of that year we find him generously interposing in behalf of his illustrious friend the poet. Milton had been in the custody of the sergeant-at-arms, and Marvell complained that excessive fees, amounting to no less than L.150, had been extorted from him. The only answer which appears in the parliamentary history, is a remark by Finch, that Milton had been Cromwell's secretary, and deserved hanging! When the poet was afterwards attacked by an anonymous assailant (whom Marvell believed, but erroneously, to be the renegade Dr Samuel Parker), the member for Hull vindicated the character of his friend; and when *Paradise Lost* appeared, he was ready to greet the immortal epic and its author, "blind yet bold," with a copy of encomiastic verses. In his capacity of legislator Marvell was diligent and independent. He wrote daily to his constituents during the sitting of Parliament, and was the friend and counsellor of the small band of senators who firmly but cautiously resisted the arbitrary spirit of the court. When Parker inculcated the slavish doctrine of divine right and passive obedience, Marvell answered him in a vein of sarcastic raillery as well as sound argument, which Swift said he read with pleasure though Parker's work had long been sunk. Another treatise by Marvell, *An Account of the Growth of*

Popery and Arbitrary Power in England, was deemed so formidable, that a reward was offered for the discovery of the printer. His poetical satires are much inferior to those in prose—grosser, and deficient in lively illustration. They were, however, greatly admired in his own day; and there is a story that Charles II. having met Marvell at a private house, was so pleased with the conversation of the wit, whose works he had read, that he attempted to win him over to the court. With this view he despatched Danby, the lord treasurer, to Marvell's lodgings, "in one of the small courts of the Strand, up two pair of stairs;" and the treasurer offered a sum of L.1000, with a promise of future favours,—all which, it is said, Marvell steadily refused, though he was obliged, on the departure of the courtier, to send to a friend for the loan of a guinea. We have no faith in this traditionary anecdote, either as respects the king's liberality or Marvell's poverty, but it illustrates the popular opinion as to Marvell's simplicity and integrity of character. He died on the 20th of August 1678. His death was so sudden as to give rise to a suspicion of his having been poisoned, for which, however, there is not the slightest evidence or authority. His remains were interred in the church of St Giles-in-the-Fields, at the expense of his constituents, who also voted a sum for a monument; but the servility or resentment of the rector prevented the ashes of the patriot and friend of Milton from receiving this distinction. His memory was long cherished by the adherents of the "good old cause;" and besides his controversial and political services, Marvell had written some minor poems of great tenderness, fancy, and beauty, which were deservedly popular. His lyrical stanzas on the sailing of the emigrants for Bermudas, *Safe from the Storms and Prelates' rage*, form one of the finest strains of the Puritan muse. A complete collection of Marvell's works was published in 1777 in three vols. 4to, by a native of Hull, Captain Thompson, who had inherited the enthusiasm of a former generation for Marvell, but appears to have been lamentably deficient in editorial diligence and literary information. (R. C—S.)

MARWAR. See JOUDPORE.

MARY (Heb. מרים, Gr. *Μαριαμ* or *Μαρια*). Of persons bearing this name, no less than seven, if not eight, are mentioned in different parts of the sacred volume. They are the following:—

MARY or MIRIAM, *the sister of Aaron and Moses*. She was the daughter of Amram and Jochebed, who were both of the tribe of Levi (Exod. ii. 1), and were related to each other before marriage as aunt and nephew (Exod. vi. 20), and seems to have been their eldest child (Numb. xxvi. 59). When the infant Moses was exposed by his mother in the ark upon the Nile, Miriam, then probably about eight years of age, was sent to observe the fate of her brother; and when she beheld him picked up by the attendants of the daughter of Pharaoh, and saw the interest taken in him by that princess, she availed herself of the opportunity to have him again restored to his mother, by offering to procure for him a Hebrew nurse, and, when that offer was accepted, bringing his mother as the person she had selected (Exod. ii. 4–10). On the occasion of the destruction of the Egyptians in the Red Sea after the Israelites had passed safely over, Miriam, who, in the passage giving an account of the circumstance (Exod. xv. 20), is styled "the prophetess," either on account of her skill in extempore poetry and music,[1] or because she really enjoyed divine revelations,[2] led forth a chorus of women, and guided them in celebrating with music and dancing the triumphant deliverance which their nation had obtained. Shortly after this an event occurred which presents the character of Miriam in a less favourable light. Her brother Moses had been rejoined by his wife Zipporah, who had for a considerable time before been resident with her father Jethro (Exod. xviii. 1–3); and as she was not of Israelitish but of Cushite extraction, Miriam and her brother Aaron took occasion from this to indulge what seems to have been a long cherished feeling of jealousy and envy towards Moses, by exciting a prejudice against him in the minds of the people. For this she was punished by God, by being, in the sight of all the people, afflicted with leprosy, so that "she became white as snow." On the intercession, however, of Aaron with Moses, and of Moses with God, this terrible infliction was removed; but not until she had been "shut out from the camp seven days," during which time the people of Israel suspended their journey (Numb. xii.). From this a period of nearly forty years elapses during which no mention is made of Miriam; and when at length, towards the close of the history, her name is again introduced, it is only for the purpose of informing us that, on the arrival of the Israelites at Kadesh, in the desert of Zin, she died and was buried in that place. At the time of her death it is calculated she must have been nearly 130 years of age. Her decease preceded that of Aaron by about *four*, and that of Moses by about *eleven* months, so that these three distinguished members of the same family died within the same year.[3] Eusebius says her tomb was to be seen at Kadesh, near the city of Petra, even in his time.

MARY, *the mother of Jesus Christ*. Closely as this memorable female was connected with Him with whose person, character, and work the Scriptures are chiefly occupied, it is remarkable how slender is the information which they communicate to us respecting her; indeed it is only as her history serves to illustrate that of her son, that her name seems to be mentioned at all. From the genealogy furnished by St Luke, in the third chapter of his gospel, of our Lord's descent from Adam, we learn that her father's name was Heli, a descendant of David through his son Nathan. In that passage, indeed, it is her husband Joseph who was said to be the son of Heli; but that he was so only from his connection with her, and that it is her descent and not his that is given by St Luke, seems plain, for the following reasons: 1*st*, In the genealogy of Christ's descent furnished by St Matthew, we are informed that the father of Joseph was Jacob, and not Heli; 2*d*, The entire discrepancy of the genealogy as given by St Matthew from that given by St Luke suggests the conclusion, that, as both relate to Christ's descent, the one gives his descent by his reputed father's side, and the other by his mother's side; and, 3*d*, As the great object of furnishing these genealogies is to show that Christ was lineally descended from David, and as it was only through his mother that he was connected naturally with any of the human race, it is absolutely necessary that we should regard the genealogy of St Luke as that of his maternal descent, else we shall be left with two genealogies, neither of which serves the purpose for which one of them at least must have been intended. We conclude, therefore, that whilst the genealogy of St Matthew was designed to meet the prejudices of the Jews, for whom chiefly he wrote, by showing that even Joseph, whom they supposed to be the father of Jesus, was of royal descent, that of St Luke presents to us the real descent of Christ from his royal type and ancestor through his mother, and is accordingly to be regarded as giving us her descent as well as his.[4] This is confirmed by the passages adduced by Lightfoot (*Hor. Talm.* in loc.) from the Jewish writings, where Mary is expressly spoken of as the daughter of Heli.[5]

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[1] See Rosenmüller, *Schol.* in loc.; and Wells's *Paraphrase*.

[2] Numb. xii. 2; and Micah vi. 4.

[3] Numb. xx. 1; xxxiii. 38; an Deut. xxxiv. 5. See also Dr Ad. Clarke's *Comment. on Numb.* xx. i.

[4] See Spanheim, *Dubia Evangelica*, P. i., p. 88.

[5] The supposition that Mary was an heiress (ἐπικληρος), and was, according to the Mosaic law in reference to such cases, married by one

At the time the gospel history opens, Mary was the betrothed bride of Joseph, who, though like herself of royal descent, followed the humble occupation of a craftsman or artificer (τεκτων), probably, as our translators suppose, in wood. Among the Jews it was no uncommon thing for females to be thus betrothed for a very long time before they were married; and whenever this was the case, the parties were regarded as bound to each other by as solemn ties as if they had been really married.[1] Hence Joseph is called the *husband* of Mary, and she his *wife*, though as yet their contract of marriage had not been fulfilled (Matt. i. 19, 20). The wild opinion that these two terms are to be understood in their ordinary meaning, and that Joseph, when a very old man, had espoused Mary merely to protect her in the observance of a vow of perpetual virginity, rests only on the testimony of the apocryphal *Protevangelium Jacobi*, and is so plainly contradicted by the entire tenor of the sacred narrative, as to be unworthy of serious notice. Whilst thus in her virgin state, and as yet probably very young (for females were betrothed at a very early age amongst the Jews), Mary became the mother of our Lord. The circumstances attending this event are related with much simplicity and minuteness by the evangelist Luke. From his account we learn that an angel appeared to Mary at Nazareth, and saluted her as "highly favoured of Jehovah, blessed among women;" and when, startled by the suddenness of the apparition, and perplexed with the strangeness of his salutation, she began to be afraid, he calmed her anxiety by explicitly announcing to her the honour which was intended for her, in that she should be the mother of the promised seed, to whom should be given "the throne of his father David." Amazed at such an announcement, she asked, in all the simplicity of conscious innocence, "How shall this be, seeing I know not a man;" upon which the angel informed her that she was to become a mother by the miraculous power of God, and that therefore her child should be called the "Son of God." For the confirmation of this message, he further informed her that her cousin Elizabeth, then far advanced in life, had conceived a son, and that the event was nigh at hand, which should cause her reproach to cease amongst women; and having thus assured her that in her the long-cherished hopes of every mother and every maiden in Israel were to be realized, he left her meekly acquiescing in the will of God.

Her first impulse after this occurrence was to visit her cousin Elizabeth, of whose state the angel had informed her. The meeting of these pious and honoured females was one of mutual joy and congratulation; nor did they fail to mingle with their rejoicings grateful thanksgivings to the author of their privileges and blessings. After spending three months with her cousin, Mary returned to her former residence. Here a severe trial awaited her; for Joseph, perceiving her pregnancy, and of course ignorant of its true cause, regarded her as having broken her vows of betrothal to him. Unwilling, however, to expose her to the ignominy and danger[2] of a public disclosure of her crime, he had formed the resolution of putting her away privately, when information was communicated to him in a dream of the real nature of the case, and the command of God laid upon him to relinquish his intention of putting her away, and to take her to his home as his wife. This he accordingly did, and thus came to be regarded by his neighbours as the father of Jesus.

In ancient prophecy[3] it had been predicted that the Messiah should be born at Bethlehem, and the fulfilment of this prediction was brought about by an occurrence of a nature apparently purely accidental, and wholly independent of the purposes of his parents. This was the issuing of an edict by the Roman emperor, commanding a census to be taken of all the inhabitants of his dominions, and ordaining that the name of each should be enrolled in the chief city of the tribe or family to which he belonged. As Joseph and Mary were both of the lineage of David, this necessitated their going to Bethlehem, the city of David; and it was whilst they were there that the prophecy was fulfilled. Much disorder has been introduced into the gospel chronology from the confounding of the edict mentioned by St Luke with a subsequent decree imposing a tax upon the inhabitants of Judæa, and which led to serious strife and bloodshed whilst Quirinus was proconsul of Syria. The two, however, were perfectly distinct. The edict which brought Joseph and Mary to Bethlehem, though in our version it is said to have decreed "that all the world should be *taxed*," seems to have had reference merely to the taking of a census of the people, and of the amount of their property. The word used by Luke is ἀπογραφη, which is the classical word for a *census* or *enrolment*, whereas the proper word for *taxation* is ἀποτιμησις. That such edicts were frequently issued is well known to every classical reader; and though there is no express mention in any of the profane historians of any such being sent forth at the time referred to by St Luke, yet as it is not to be supposed that they have recorded *all* the events of this nature which occurred, their silence can hardly be regarded as a sufficient reason for rejecting the testimony of the evangelist.[4] To this confounding of these two distinct edicts, many have been led by the language of St Luke himself in the second verse, where it is stated (according to our version) that "this taxing was first made when Cyrenius was governor of Syria." Here the evangelist seems at first sight to have fallen into the mistake alluded to, and of this an eager use has been made by some of the enemies of Christianity to discredit his claims as an inspired historian. His words, however, when translated so as to give them a meaning (which can hardly be said to be the case in our version), seem rather designed to guard against such a mistake, than to indicate the

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of her own tribe, who from that circumstance came to be called the son of her father, a supposition which was maintained at a very early age in the church, as we learn from Eusebius (*Hist. Eccl.* i. 7), is entirely arbitrary and unnecessary. See Crusii *Hypomnemata ad Theol. Proph.*, p. 355; and Olshausen's *Commentar*, Bd. i., seite 43; the latter of whom favours the hypothesis. Tradition assigns to the father of Mary the name of Joachim, and to her mother that of Anna. Dr Barrett thinks Heli may be found in Joachim, but by what etymological legerdemain this may be accomplished we cannot conjecture. In his prolegomena to the edition of the Gospel by Matthew, from the Dublin *Codex rescript.*, p. 44, he says,—"In hocce nomine Joachim latere nomen illud Eli, Luc. iii., 23, sive Eliakim, 2 Par. xxxvi. 4, vix dubitare potest." The confounding of Eli, Heb. עלי, with the Eli in Eliakim, Heb. אלי, says very little for Dr B.'s Hebrew scholarship.

[1] Deut. xxii. 23. "Femina ex quo desponsata est, licet nondum a viro cognita, est uxor viri; et si sponsus eam velit repudiare, oportet ut id faciat libello repudii." (Maimonides ap. *Buxtorf. de Divortio*, p. 76.)

[2] By the law of Moses such crimes were to be punished with death by stoning. (Deut. xxii. 23, 24.)

[3] Micah v. 2.

[4] The statement of Dio Cassius, which is supported by the testimony of Tacitus (*Annal.* i. 11), and of Suetonius (*Octav.* c. 101), that Augustus left behind him at his death a *breviarium* or *rationarium* of the Roman empire, in four volumes, of which the third *complectebatur quæ ad milites, quæque ad reditus sumptusque publicos, pertinebant*, renders it extremely probable that that monarch had taken much pains to have accurate returns made from all parts of his dominions. That this was the case, is indeed expressly stated by Cassiodorus, iii. 52. See also Suidas *in voc.* ἀπογραφη.

author's having fallen into it. According to a usage not uncommon in the New Testament, πρωτη seems to be used for πρωτερα;[1] and in this case the proper rendering would be, "this census took place *before* Cyrenius (or Quirinus) was governor of Syria;" a statement which seems thrown in parenthetically by the historian, for the purpose of informing his readers that the event to which he refers was not the famous and well-known taxing under Quirinus (commonly called, as he himself records in Acts v. 37, "*the* taxing," by way of eminence), but was antecedent to it.[2]

Owing to the multitudes of people whom this edict had brought together to Bethlehem, Joseph and his wife, on their arrival, found themselves unable to procure any better accommodation than what was afforded them by the stable of a public lodging-house. Here Mary was delivered of her first-born son, whom she herself swathed and laid in the manger. Amongst the busy crowd then assembled at Bethlehem this event excited no attention; but it was too important to be allowed to pass unregarded by Heaven, and accordingly an angel was commissioned to announce it to some pious shepherds that same night, as they were watching their flocks in the adjoining fields. Gladdened with the joyful news that the long-expected Messiah had at length appeared, these pious men lost no time in going to Bethlehem, that they might see the thing which had come to pass, and might offer their adoration to their infant Saviour. The intelligence they brought was received by Mary and Joseph with astonishment, and by the former carefully stored up in her remembrance. (Luke ii. 8-19.)

On the termination of the time appointed by the Mosaic law for the continuance of a woman's uncleanness after child-birth,[3] Mary went up to Jerusalem to present her son to the Lord, and to offer the sacrifice appointed in such cases.[4] These rites observed, she returned with her husband to their usual residence at Nazareth (Luke ii. 39). From this place they were in the habit of going up to Jerusalem every year at the feast of the passover (ver. 41); and it seems to have been on the occasion of one of these visits that the Magi from the East came with their offerings and adoration to Christ. The occurrence of this event is commonly regarded as having taken place immediately after the visit of the shepherds; but a comparison of the facts stated by St Matthew with those stated by St Luke forbids the entertaining of such a supposition. From the former we learn, that immediately on the visit of the Magi, Joseph and his wife fled into Egypt, where they abode till the death of Herod. But the latter informs us, that six weeks after the birth of Christ, he was taken up to the temple, and from thence carried down to Nazareth. From this it is plain that the visit of the Magi, and the consequent flight into Egypt, could not have taken place *before* the dedication in the temple, and must therefore be referred to a subsequent period.[5] It was on the occasion of another of these visits that the scene between Christ and the Jewish rabbis took place, when, after an absence from his parents of three days, he was found by his anxious mother sitting with the doctors in the temple, both hearing them and asking them questions (Luke ii. 42-52).

Some time before our Lord's entrance upon his public ministry, Mary seems to have lost her husband. This is rendered probable, not only from the circumstance that no mention is made after this period of Joseph in the gospel history, but also from the freedom with which Mary appears to have moved from place to place; a freedom hardly consistent with her duties as a wife whose husband was still alive. As confirmatory of this it may be mentioned, that it was admitted as an acknowledged fact in the early ages of the church, that she supported herself by weaving; and hence Celsus calls her Χερνητις, and Tertullian *Quæstuaria*. Her residence seems to have been principally at Capernaum, on which account probably this place was called Christ's "own city" (Mat. ix. 1), as her house would be the place to which he would naturally retire during the intervals of his public labours. She is mentioned as having been present at the marriage at Cana in Galilee, where he commenced his miraculous works by turning water into wine (John ii. 1). Shortly after this, whilst he was teaching in the synagogue at Capernaum, she endeavoured to induce him to desist, fearing probably lest he should offend the people by his pointed rebukes; but he resisted her entreaties, declaring that no earthly connections could be so dear to him as those spiritual unions which he sought to form by the truths he was teaching. On the occasion of his going up to Jerusalem for the last time before his death, she was one of those who accompanied him; she followed him to Calvary, beheld him elevated on the cross, and retired not until she saw him expire. As she stood gazing on him, along with some of his followers, he commended her to the care of his beloved disciple John, who from that time took her to reside in his own house. We learn from Acts i. 14, that she was amongst the disciples at Jerusalem when they were waiting for the gift of the Holy Spirit. An uncertain tradition informs us that she removed with John to Ephesus when he went to reside there, and died and was buried in that place. Other accounts state that she died and was buried at Jerusalem, which is perhaps the more probable statement of the two. By the Roman Catholic church the Virgin Mary has been deemed worthy of divine honours, and has even been made to occupy a more prominent place in the devotions of the people than the Saviour himself.[6] Such reverence for the Virgin was unknown in the early ages of the church, but the way was gradually paved for it by the importance which was attached to discussions respecting her in the writings of the Fathers, and by the extravagant terms of eulogy in which they spoke and wrote regarding her. From styling her θεοτοκος, θεομητηρ, δεσποινα ἁγια και ἀειπαρθενος, as even Chrysostom writes of her; from speaking of her as "the sacred treasure of the universe, the quenchless lamp, the crown of virginity, the sceptre of orthodoxy, the temple indestructible, the tenement of the infinite, both a virgin and a mother," as Cyril of Alexandria describes her,[7] the transition was not difficult to the offering of divine homage to the object of such unwarranted eulogium. Mr Newman, in his *Essay on the Development of Christian Doctrine*, p. 50, adduces the growth of "the doctrine of the θεοτοκος, or Mother of God, into *hyperdulia*," as one of the instances of what he calls "moral developments;" that is, developments that "are not proper matter for controversy, but are natural and personal, substituting what is congruous, desirable, pious, decorous, generous, for strictly logical inference." Of the utter absence of all logical strictness from the process of this "development" there can be little doubt; but whether the result merits the laudatory epithets Mr Newman has heaped together must be questioned. To most people the process will appear rather as affording a striking illustration of the tendency of all religious error to become more and more gross, and to carry those who embrace it still farther and farther into delusion. The first step was to declare the perpetual virginity of Mary, which was done about the middle of the fourth century. Then came conjectures about her miraculous transit from earth to heaven, which gradually led to a belief in her assumption. Next, Radbert in the ninth century propounded the belief that Mary bore her son " Omnino clauso utere . . . sine dolore, et sine gemitu," a dogma which, however, was opposed at the time by Ratramn. About the same time festivals were appointed in celebration of her birth and of her ascension. In the tenth century men began to pray to her and to worship her; Saturday was dedicated to her, and an office of the " Holy Mary" appointed to be used. In 1140 the doctrine of the immaculate conception of Mary began to be taught, though not without strenuous opposition on the part of many, among whom St Bernard was the most conspicuous. This dogma became soon afterwards a bone of contention between the Dominicans and the Franciscans,—the former of whom, following Thomas Aquinas, opposed it; while the latter, following Duns Scotus, defended it. Two new festivals were instituted in honour of Mary,—the festival of the "Presentation," appointed by Pope Gregory IX. in 1372; and the festival of the " Visitation," appointed by Pope Urban VI. in 1389. In 1387 a great advantage was gained by the advocates of the immaculate conception, in consequence of a decision of the university of Paris, that all who graduated in it should assent to a condemnation pronounced by the university on all who should decidedly reject this doctrine,—a decision which speedily assumed the character of a positive declaration in favour of it. In 1439 a council held at Basle decreed that the doctrine of Mary's conception without sin, and her immunity from actual sin, was to be embraced by all Catholics,— " Tanquam piam et consonam cultui ecclesiastico, fidei catholicæ, rectæ rationi et sacræ Scripturæ." Other universities followed the example of that of Paris; the mendicant orders became zealous preachers of the doctrine; miraculous legends concerning her, such as that of the conveyance of her house from Nazareth to Loretto, where it was set up as a shrine dedicated to her, were plentifully circulated; and a great impulse was everywhere given to the worship of the Virgin, as the being " by whose dispensation alone any creature could obtain any grace or virtue from God." Art lent its aid to the strengthening of this cause, and pictures of the Blessed Virgin, from the highest style which painting has reached, down to the coarsest daubs, kept continually before the minds of the people the leading facts of her history as taught by the church, and the pretensions which the church had set up in her behalf. By these means her worship was successfully established; her name was invested with every attribute of glory and majesty; she was hailed as the Mother of Mercy, the Queen of Heaven, the Fulgid Gate of Heaven, and such like epithets; prayers were offered to her for the highest blessings; and she gradually ascended in the view of all good Catholics, until her glories obscured those of her Son, and the place due only to Him came to be assigned to her. Her image is now in every Roman Catholic church, and in every house where a Roman Catholic dwells. At corners of streets, and where roads cross, chapels are erected to her honour, adorned with flowers, and illuminated with tapers, and round which, at the hours of vespers, multitudes may be seen kneeling in prayer. Her image is worn as an amulet on the breast, or woven into chaplets for the head; and even on the uniform of the pope's scudieri the Madonna and Child figure as the appropriate badge of their office.[1] The present pope has put the colophon on this extended volume of blasphemy and folly, by authoritatively declaring (in 1855) the immaculate conception of the Virgin to be a doctrine of the Catholic church. It is to be regretted that, even by Protestant writers, a degree of importance has been attached to inquiries respecting her, which nothing in Scripture would seem to authorize. How many, for instance, have contended for her perpetual virginity, as if it were a matter on which the whole of our religion depended. Such matters, however, " do not affect," as the great Basil truly remarks, " the doctrine of godliness; for though until the birth of Christ her virginity was necessary, what happened afterwards is a matter not worthy of anxious inquiry."[2] A more interesting question is that respecting the fact of her having had any children by Joseph after the birth of Christ, because upon the answer given to this depends the meaning which we are to attach to those passages that speak of our Lord's " brethren and sisters." On this different opinions have been entertained:—1. That these appellations are to be taken according to Hebrew usage, as merely signifying *near relations*;[3] 2. That they designate the children of Joseph by a previous marriage; 3. That the parties so designated were really the children of Mary and Joseph, and so the german brothers and sisters of our Lord according to the flesh. What renders this last opinion the most probable is, that Jesus is called Mary's πρωτοτοκος, or first-born; and that Matthew, in connection with this, is careful to state that Joseph knew her not *until* (ἕως) she had brought forth her first-born son. This would seem to imply that she had other children afterwards by him. This view is also the most natural in such passages as Matt. xiii. 55; Mark iii. 31; Luke viii. 21; John ii. 12; vii. 3, where the brethren of Christ are mentioned in connection with Mary. " It would be very forced work," to use the words of Neander, "to suppose that in all these passages ἀδελφοί is placed for ἀνεψιοί."[4]

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[1] Winer's *Grammatik des Neutest. Sprachid.*, p. 201. Stuart's *Syntax of the New Testament Dialect*, in the "Biblical Cabinet," vol. x., p. 120.

[2] See Lardner, *Credibility*, part ii., ch. 1; Macknight, *Harmony*, Chronol. Diss. i., ch. 13; Tholuck, *Glaubwürdigkeit der Evang. Gesch.*, p. 184 ff. Wieseler, *Chronologische Synopse d. vier Evangelisten*, p. 109 ff.

[3] Exod. xiii. 2.

[4] Levit. xii. 6-8.

[5] Macknight's *Harmony*, sect. 11; and Doddridge *in loc.*

[6] For illustrations of the length to which this was carried during the middle ages, see the extracts in Gieseler's *Kirchen Geshichte*, Bd. ii., Abt. ii., p. 463. See also Abt. iv., p. 335; Eng. tr., vol. iii., p. 339, &c. For evidence on the same point, in relation to the present day, see Seymour's *Evenings with the Romanists*, p. 239 ff.

[7] *In Actis Ephes.*, p. 33, ap. Suicer. *Thes. Eccl.* ii., 304.

MARY *Magdalene*, so called apparently from *Magdala*, a castle, and probably also a village, near Gamala and the baths of Tiberius, on the eastern shore of the sea of Galilee (Matt. xv. 39).[5] This was in all probability her birthplace, and from it she was named, to distinguish her from the other Marys who followed Christ. She has been often confounded with Mary the sister of Martha and Lazarus, and also with the " woman who was a sinner," mentioned in Luke vii. 36, &c., but in both cases without any sufficient reason. Equally unfounded is the notion, that before her conversion she was a person of abandoned character; a notion which, though resting on no better authority than that of some monkish legends, has nevertheless become so generally received, that few even in Protestant countries ever think of questioning its accuracy. The only passage of Scripture, however, that can be quoted as favouring this opinion, is that in which it is said that " out of her went seven devils" (Luke viii.). But this cannot be admitted as evidence in support of the point in question; for, whatever may be the conclusion to which we come as to the nature of that diabolical possession which prevailed in the days of our Lord, one thing is certain in regard to it, which is, that to be afflicted with it did not imply in the individual so visited any peculiar moral depravity; so that, though the case of Mary Magdalene was one of unusual severity (the number *seven* being the number of completeness), it by no means follows from this that she was not a virtuous, nay, pious female. On the contrary, the evidence from Scripture seems rather to favour the supposition that she was a person at once of blameless character and respectable station. She is introduced to us for the first time in the society of Joanna, the wife of Chuza, steward of Herod's household (ἐπίτροπος, *præfectus domus*), with whom she was associated in ministering to the wants of our Saviour "out of their substance" (ὑπάρχοντα, *opes facultates*); and from the language used by Mark (ch. xv. 41), it would seem as if this had been the usual practice of these pious females whenever he paid a visit to Galilee. Had she been, as is commonly supposed, a mere common prostitute before her conversion, it is difficult to understand how she should either associate with persons of such rank as Joanna, or be possessed of the means of such liberality towards Christ.[1]

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[1] Clausen, *Kirchen-verfassung, Lehre und Ritus des Catholicismus und Protestantismus*, p. 723.

[2] *Homil. de Christi generatione*, ap. Suicer. *Thes. Eccl.* ii. 306.

[3] Bishop Pearson *on the Creed*, p. 174, folio ed.; Edwards' *Exercitations on Scripture*, p. 143; and Pott, *Proleg. in Epist. Jacobi, Nov. Test. Koppianum*, vol. ix., p. 90, &c.

[4] *Life of Christ*, Eng. tr., p. 32; Comp. De Wette on Matt. i. 25, in his *Exegetisches Handbuch*.

[5] Lightfoot, *Hor. Talm.* in loc.; Winer, *Realwörterbuch*; and Kitto's *Bib. Cyclopædia*, art. *Magdala*.

On the occasion of our Lord's going up to Jerusalem from Galilee, immediately before his death, Mary Magdalene was one of those by whom he was followed; nor does she seem to have left him as long as he continued upon earth. She was one of those who beheld him from a distance when he was hanging upon the cross (Mark xv. 40); and when he was taken down and buried, it was she and Mary Salome who sat over against the sepulchre and beheld where he was laid (Matt. xxvii. 61; Mark xv. 47). From the sepulchre she returned with her companion into the city to procure materials for embalming his body; and having rested on the Sabbath, they came at the dawn of the third day to perform this office of respect to their departed Lord. Contrary to their expectations and fears, they found the stone which they had seen placed upon the mouth of the tomb rolled away, and free entrance afforded to its interior. Stooping down and looking in, they were startled to find the body of Jesus gone; but as they wondered, an angel appeared, who informed them of his resurrection, and at the same time commanded them to carry the tidings of this event to the rest of the disciples (Matt. xxviii. 7). Amazed and perplexed, they fled from the sepulchre, and announced to their company what they had seen; upon which Peter and John hastened to satisfy themselves of the correctness of their report, by returning with them to the place where Jesus had been interred. When the others returned home, Mary seems to have remained by the empty sepulchre to weep; and "as she wept," we are told, "she stooped down and looked into the sepulchre, and seeth two angels sitting, the one at the head and the other at the feet, where the body of Jesus had lain." By them she was asked the cause of her tears; to which she answered, that it was because they had taken away her Lord, and she knew not where they had laid him. During this conversation, Jesus himself drew near and addressed her; but, stupified with grief, she did not at first recognise his voice, and, intent upon gazing into the sepulchre, she answered his inquiries as to what she wept for, and what she sought, without turning herself, under the impression that he was the gardener. To recal her recollection, Jesus addressed her by name; upon which she immediately recognised the well-known voice, and turning herself, exclaimed, "Rabboni, which is to say, Master." After a brief conversation, he sent her to announce to the disciples that she had seen him, and that he was about to ascend to heaven. This command she obeyed; and from this time forward we find no mention made of her in the New Testament. As to certain traditionary accounts of subsequent actions and journeyings in which she is said to have been engaged, they bear too obviously the marks of mere legendary fiction to be worthy of notice.

Mary, *the sister of Martha and Lazarus.* These three individuals composed the members of a family, than which none was more beloved and honoured by our Lord in the days of his flesh. Their residence was at Bethany, a village not far from Jerusalem, where Martha seems to have been a householder; and thither our Lord was in the habit, apparently, of frequently retiring during the intervals of his public labours. The name of Mary is first introduced, in connection with that of her sister, in the account given of a visit paid by Christ to their abode, during one of his journeys; on which occasion, whilst Martha busied herself in caring for the hospitable entertainment of her guest, Mary sat at his feet to receive his instruction (Luke x. 38, &c.). The next mention that is made of her is in the touching and striking account given by John (ch. xi. 1–46) of the death and resurrection of Lazarus; and she appears for the last time shortly subsequent to this, on the occasion of an entertainment given to our Lord, a few days before his crucifixion, by Martha, when she anointed his feet with precious ointment, and wiped them with the hair of her head (John xii. 1-9).

Mary, *the mother of James and Joses, and Simon and Judas.* She is the same who is elsewhere called the wife of Cleophas (John xix. 25), or Alphæus, these two being only different modes of Grecizing the Hebrew חלפי, *Chalpai.* The common opinion is that she was the sister of the Virgin Mary, an opinion founded on John xix. 25. But as it is not very probable that there would be two sisters in one family of the same name, it seems better to adopt the suggestion of Wieseler (*Theol. Studien und Kritiken*, 1840, p. 648), that in this passage *four* persons are enumerated—Mary, Mary's sister (whose name is not given), Mary the wife of Cleophas, and Mary of Magdala.

Mary, *the mother of John Mark.* (Acts xii. 12.)

Mary, a pious member of the church at Rome. (Rom. xvi. 6.) (W. L. A.)

Mary I., *Queen of England*, was the daughter of Henry VIII. and Catherine of Aragon, and was born on the 18th of February 1516. She ascended the throne on the 6th of July 1553, married Philip II. of Spain on the 25th of July 1554, and died on the 17th of November 1558. (See England.)

Mary, *wife of William III.*, was the eldest daughter of James II. and Ann Hyde, and was born in 1662. She married the Prince of Orange in 1677, shared the throne with her husband in 1688, and died in 1694. (See Britain.)

Mary, *Queen of Scots*, was the daughter of James V. of Scotland and Mary of Lorraine, and was born on the 8th of December 1542. She married the Dauphin of France, afterwards Francis II., on the 24th of April 1558; assumed the personal government of Scotland on the 19th of August 1561; married Lord Darnley on the 29th of July 1566, and Bothwell, on the 15th of May 1567; was forced to retire from the throne on the 17th of June 1567; was imprisoned by Elizabeth in 1568, where she remained till her execution on the 8th of February 1587. (See Scotland.)

MARYBOROUGH, a town of Ireland, capital of Queen's county, is situated on a small tributary of the Barrow, 50 miles S.W. of Dublin. It is straggling and meanly built, consisting chiefly of one long irregular street on the Dublin and Limerick road. It has, however, several good public buildings, among which are,—the parish church, a Roman Catholic chapel, several Dissenting chapels, court-house and prison, barracks, infirmary, and lunatic asylum. It returned two members to the Irish parliament till the Union, when it was disfranchised. Pop. (1851) 2079.

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[1] For a complete investigation of this point, see Lardner's Letter to Jonas Hanway, Esq., *Works*, vol. v., 4to. ed. See also Macknight's *Harmony*, sect. 43.

MARYLAND, one of the United States of North America, bounded on the N. by Pennsylvania, E. by Delaware and the Atlantic, and S. and W. by Virginia, from which it is separated by the River Potomac; and extending from 38. to 39. 44. N. Lat., and from 75. 10. to 79. 20. W. Long. Its form is very irregular; its greatest length is 190, and its greatest breadth 120 miles; area 9356 square miles. The surface of Maryland may be regarded as consisting of two distinct parts. The one comprehends the high lands in the W. of the state, traversed by several ridges of the Alleghany Mountains, and extending in a narrow strip of land eastward as far as the lower falls of the rivers. The other portion, which is low and flat, is subdivided into two parts by Chesapeake Bay. These are called respectively the Western and the Eastern Shore; the former consisting of a peninsula formed by the estuary of the Potomac and Chesapeake Bay, and the latter of part of that peninsula lying between Chesapeake Bay and the Atlantic. Of this last, the north-eastern part is occupied by the state of Delaware, while the southern extremity belongs to that of Virginia. In the mountainous district the principal ridges are South-East Mountain or Parr's Ridge, terminating at Sugar-Loaf Mountain on the Potomac. In a direction nearly parallel to this range, extends Catoctin Mountain, reaching the river at the Point of Rocks. Further up, the river is crossed at Harper's Ferry by the Blue Ridge or South Mountain, and at Hancock by the Kittatinny. In the extreme W. of the state rise the main ridges of the Alleghany Mountains, besides Rugged Mountain, Wills Mountain, and other detached chains. None of these ridges have any great elevation; and the valleys which lie between them are remarkable for the fertility of their soil and the mildness of their climate. The eastern and western shores of the state are very similar to each other in soil and productions. The soil is alluvial, and consists in general of a mixture of sand and clay; and though not very fertile by nature, is easily rendered productive by the use of manure, which is supplied in large quantities by the marl beds in the country. The climate is temperate, and in general salubrious, with the exception of some of the low-lying country near Chesapeake Bay, from which rise noxious exhalations, especially during the months of autumn. The principle feature in this part of the state is the Bay of Chesapeake which divides the whole region into two parts from N. to S., and gives the outline of the state a very irregular appearance. This great estuary has a total length of 180 miles, of which 120 are in this state, and a breadth varying at different places from 7 to 20 miles. It is navigable for the largest vessels throughout its entire length, and it abounds in fine fish and oysters. It receives many rivers of various sizes, and its coasts are deeply indented by numerous bays and creeks. The surface of the bay is studded with many islands, the most considerable of which is Kent Island, opposite the city of Annapolis, about 12 miles in length. The Potomac River, the largest of those that fall into Chesapeake Bay, and which forms the boundary between this state and that of Virginia, rises in the Alleghany Mountains, and flows in an irregular course, first nearly E. and afterwards S. and S.E., till it enters the Bay of Chesapeake towards its southern extremity between Point Look-out and Smith's Point. Its width at its mouth is 7½ miles, and it is navigable for the largest vessels as far up as Alexandria; while by means of canals the falls which occur not far above this are avoided, and the river rendered navigable for boats as far as Cumberland, 191 miles above Washington. The scenery of this river is very fine, especially at these falls, which, though not very high, are among the most interesting objects of the kind in the States; and at Harper's Ferry, where the river rushes through a defile in the Blue Mountains. The principal affluents of the Potomac in this state are the Monocacy River, Antietam and Conecocheague Creeks. Besides these are,—the Patuxent, which flows in a direction nearly the same as the Potomac, rising in Parr's Ridge, and falling into Chesapeake Bay, and is navigable as far as Nottingham, 50 miles up; the Patapsco, falling into the bay near Baltimore; the Susquehanna, which is for the greater part of its course a Pennsylvanian river, but which falls into Chesapeake Bay in this state. The Elk, Chester, Choptank, Nanticoke, and Pocomoke, all flow to the eastern shore, and are navigable for 30 or 40 miles. The only river in Maryland which does not flow into Chesapeake Bay is the Youghiogeny, which rises in the mountains of the extreme W., and flows northwards into the Ohio. In a geological point of view, the whole of the level region of Maryland consists of recent formations, containing many interesting fossils; while the mountain district consists of metamorphic strata, such as gneiss and mica, slate, granite, limestone, &c.; and is rich in coal and iron mines. Maryland contains a considerable extent of forest land; the principal trees are,—oak, pine, chestnut, cedar, ash, beech, poplar, and elm. The principal agricultural productions of this fertile and well-cultivated district are tobacco, wheat, and Indian corn; besides which large quantities of oats, rye, flax, hay, potatoes, peas, beans, &c., are raised. The number of farms in the state in 1850 was 21,860, comprising 2,797,905 acres of cultivated land; and the total value of the farms, with their machinery and implements, was L.18,676,233. The live stock in the same year included 75,684 horses, 219,586 head of cattle, and 177,902 sheep; and amounted in total value to L.1,166,174. In the agricultural produce for the year ending June 1, 1850, the principal items are the following:—Wheat, 4,494,680 bushels; rye, 226,014 bushels; Indian corn, 10,749,858 bushels; oats, 2,242,151 bushels; tobacco, 21,407,497 lb.; potatoes, 973,932 bushels; and butter, 3,806,160 lb. In the aggregate amount of tobacco produced, Maryland is the third of the States; and in comparison with the population, the second. The manufactures of Maryland are numerous and important. There were, in 1850, 24 cotton factories, employing 3022 hands, and producing stuffs to the value of L.441,772; 38 woollen factories, employing 362 hands, and producing stuffs to the value of L.61,488; 51 furnaces, forges, &c., employing 2699 hands, and producing 59,855 tons, valued at L.523,519; and 116 tanneries, producing leather to the value of L.229,820. Total number of manufactories in the state (1850), 3863; capital invested, L.3,073,588; hands employed, 30,124; value of raw material, fuel, &c., L.3,609,738; value of produce, L.6,870,355. The improvements in the internal communications of this state have been very extensive, and Maryland has in this department displayed more energy and enterprise than caution and prudence. There are three extensive canals—the Chesapeake and Ohio Canal, which has only been completed as far as Cumberland, a distance of 200 miles from its commencement at Alexandria, and which cost up to the year 1839 more than L.145,833; the Susquehanna Canal, communicating with the interior of Pennsylvania; and the Chesapeake and Delaware Canal, which affords a water-communication with Philadelphia. There are also many railways in the state. Of these the Baltimore and Ohio, and the Baltimore and Susquehanna lines, with their several branches, are the principal, and have a total length of 514 miles.

The commerce of Maryland is very great, owing to the

Maryland.

facilities for trade afforded by its excellent harbours, its navigable rivers, canals, and railways. The principal articles of export are,—flour, wheat, pork, and tobacco; and the total value of goods exported from the state in 1850 was L.1,451,533. The imports for the same year amounted in value to L.1,275,886. For the year ending June 30, 1855, the respective values were,—exports, L.2,165,413; imports, L.1,623,781.

The number of vessels built in the state in the year ending June 30, 1855, was 122, with a tonnage of 22,524. Fishing is carried on in Chesapeake Bay, and large quantities of fish are taken, consisting principally of herring, shad, eels, perch, mullet, &c.

The state of Maryland is divided into 21 counties; and the principal towns are,—Baltimore, Cumberland, Frederick, Hagerstown, and Annapolis. Though not the largest town, Annapolis is the capital of the state. The present government of Maryland, which was settled by the constitution of 1851, consists of a Governor, elected for four years, with a salary of L.750 a-year; a Senate of 22 members, also elected for four years; and a House of Representatives of 74 members, elected for two years. There are three districts in the state, from each of which in rotation the governor must be chosen. The franchise extends to every white male above the age of twenty-one, a citizen of the United States, and who has resided for a year in the state, and six months in the county or town for which he votes. The qualifications for members of the legislature are, that they shall be not less than twenty-five years of age for the Senate and twenty-one for the House of Representatives, and have resided three years in the state and one in the district for which they are elected. The judicial establishment consists of an orphans' court in each county, composed of three judges, elected by the people for four years; eight circuit courts, each presided over by a judge elected for ten years; and a court of appeal, with four judges elected from as many districts for ten years, one of whom is appointed chief justice by the governor and Senate. Judges must retire at the age of seventy. The religious institutions in Maryland consist of an aggregate of 909 churches, with property amounting to L.822,476. The proportions of places of worship belonging to the different sects are as follows:—Baptists, 48; Episcopalians, 133; Friends, 26; German Reformed, 22; Lutherans, 42; Methodists, 479; Moravians, 12; Presbyterians, 57; Roman Catholics, 65; Union Church, 10; minor sects, 10. The educational establishments consisted in 1850 of 11 colleges, with 91 teachers and 992 students; 907 public schools, with 1005 teachers and 33,254 scholars; and 224 academies and other schools, with 489 teachers and 10,677 scholars. The total number attending school in the state in 1850 was 62,063; and the number of adults unable to read or write was 41,877. The amount of the public funds expended for purposes of education was in the same year L.15,862; and the amount raised by taxation was L.18,055. The principal public institutions in the state are at Baltimore, and consist of a state penitentiary, a lunatic asylum, &c. The amount of the state debt of Maryland, September 30, 1856, was L.3,114,498; the total receipts for the year ending at that date, L.256,359; and the total expenditure for the same year, L.256,356.

The earliest settlement of Europeans in the territory of this state was in 1631, when William Claiborne founded a colony on Kent Island.

The district was named Maryland from Henrietta Maria, queen of Charles I., who granted a charter for the territory to Lord Baltimore, a Roman Catholic, in 1632. A colony, composed chiefly of Roman Catholics, fugitives from religious persecution, settled at St Mary's in 1634 under Leonard Calvert, brother of Lord Baltimore. The government was liberal and democratic, the legislative functions being exercised by the lord proprietary and the representatives of the people. A contest, however, soon arose between the governor and the people about their respective rights in the legislature; the former endeavoured to force on the colony a system of laws framed by himself, and the latter resisted this attempt, restricting his power to a right of veto on any measure passed by the people. The governor ultimately gave way, and the constitution of the colony became of a more popular character. During the time of the civil war in England, the governor, a Catholic, and an adherent of the king's, expelled from the colony a number of Puritans, who settled in Virginia, but afterwards returned, and attempted to gain the supremacy in Maryland. After partial successes on both sides, the legislature passed in 1649 an Act of Toleration, in which Catholics, Quakers, and Puritans, who had now all in turn experienced the evils of persecution, had a share. Soon afterwards the adherents of the Commonwealth, which was now in power in England, having gained the upper hand in the colony, and reinforcements having been sent to their assistance, the lord proprietary was overthrown, but not until after a bloody battle. After the restoration of Charles II., the government was restored to the Baltimore family, with whom it continued till the Revolution of 1688. After that event the affairs of the colony were managed by governors appointed by the crown, until 1715, when Benedict Leonard Calvert, the heir of the Baltimore family, who had embraced the Protestant religion, was reinstalled as governor of the colony. After this period Maryland continued to make progress in population and manufacturing industry, though the policy of Great Britain, which was calculated to repress the progress of the colony, was felt as a great hinderance. Long and tedious disputes were carried on between Maryland and Pennsylvania, which were only finally settled in 1785, when the frontiers were adjusted as they at present stand. No remarkable engagement took place here in the revolutionary war; but Annapolis was the scene of some of the meetings of the Congress and of Washington's resignation of the command at the end of the war.

Maryland is a slave-holding state; and though after the Revolution there was a strong tendency to emancipation, all public measures of that kind were checked by an article in the constitution of 1836.

Population in 1850.

	Male.	Female.	Total.
Whites	211,187	206,756	417,943
Free Coloured	35,192	39,531	74,723
Slaves	45,944	44,424	90,368
Total	292,323	290,711	583,034

Maryport.

MARYPORT, a seaport and market-town of England, county of Cumberland, is situated near the mouth of the Ellen, 29 miles S.W. of Carlisle. The town is neat and well built, and has entirely risen within the last century. The only public buildings of importance are the town-hall, the market-house, and the bridewell, which are elegant edifices. Maryport has a chapel of ease, and places of worship for Presbyterians, Methodists, Independents, Baptists, Quakers, and Roman Catholics. The town has also national and British schools, a mechanics' institution, a reading-room and library, and a savings-bank. The inhabitants are principally employed in ship-building, and the manufacture of sail-cloth, ropes, cordage, and other articles for ships. The trade of the place is very considerable, consisting chiefly in coal, which is conveyed through Maryport from Northumberland and Durham to Scotland and Ireland. In 1855 283,603 tons were shipped here. Coke, lime, and stone are also exported; and the imports consist of cattle, timber, flax, and iron. The harbour is dry at low water. A steamer plies between this town and Liverpool, the Isle of Man, and Dublin, every week in summer, and every fortnight in winter. The town had in 1855, 105 vessels, of 15,987 tons burden; and during that year the number of vessels that entered the harbour was 273, with a tonnage of 39,052; and of those that left, 2654, with a tonnage of 229,658. The market-day is Friday; and fairs are held twice a-year. Pop. of the chapelry (1851), 5698.

MARYSVILLE, a post-town, capital of the county of Yuba, in the state of California, North America, is situated on the right bank of the River Yuba, about a mile above its confluence with the Feather River, and 100 miles N.N.E. of Benicia. Steamers ply regularly between Marysville and San Francisco, touching at Sacramento. Pop. (1853) 8000.

MASACCIO, a celebrated painter of the Florentine school, was born in 1402 at San Giovanni in the Valdarno. His real name was Tommaso Guidi, but his unfitness for the cares of ordinary life procured for him at an early age the nickname of Masaccio, or "Helpless Tom." Receiving the first lessons in his art from Masolino da Panicale, he was employed under that master in painting the Brancacci chapel in the church of the Carmine at Florence. He also carefully studied the sculptures of Ghiberti and Donatello, and learned perspective from Brunelleschi. About 1430 Masaccio seems to have visited Rome, and there, according to Vasari, he was employed in the execution of several important works. On the return, however, of his patron, Cosmo de' Medici, from exile in 1434, he went back to Florence, and was engaged to complete the paintings of the Brancacci, left unfinished by the death of his old master Masolino. He died, however, in 1443, before he had fulfilled his engagement. The suddenness of his death, and the envy in which he was known to be held by his rivals, combined to originate the suspicion that he had been poisoned.

Ever working with a clear perception that painting is simply a close imitation of nature, Masaccio surpassed all his contemporaries in the easy postures of his figures, in the simplicity and dignity of his draperies, and in his natural and harmonious colouring. So unprecedented was his skill in foreshortening, and his knowledge of perspective, that he may be said to have introduced a new era in the annals of painting. The frescoes in the church of the Carmine at Florence were his masterpieces, and were zealously studied by Raphael and other great painters of the fifteenth and sixteenth centuries. In his epitaph, written by Annibal Cavo, it is said that Michael Angelo was the teacher of other painters, but the pupil of Masaccio.

MASANIELLO, the abbreviated name commonly given to TOMMASO ANIELLO, a fisherman born at Amalfi in 1622, who, at the age of twenty-five, became chief of the celebrated revolution in Naples which bears his name. While under Spanish dominion that country was subjected to the greatest misgovernment. The ambition of Philip III. and Philip IV., both of whom required extraordinary funds to carry on the wars of Lombardy and Catalonia, scarcely surpassed the avidity and selfishness of the exacting viceroys employed by them to plunder the Neapolitans. A confused and embarrassed administration; a corrupt magistracy; venal employées who enriched themselves as a reward for other services; an oppressive distribution of taxes, which rendered a system of violence necessary in levying them; a ready compliance with all the arbitrary acts of the nobility, who set the law at defiance and enjoyed a total immunity from all burdens of the state; and last, though not least, an organized system of brigandage, which the government was as powerless and unwilling to check as the nobles were interested in upholding;—such was Naples under the viceregal government of Spain. This state of things, long hateful to the Neapolitan people, reached its height under his excellency the Viceroy Ponce de Léon, Duke d'Arcos. Taxes were multiplied, more especially on the articles of daily consumption; and in 1647 even fruit, which in summer forms almost the only food of a large portion of the populace, did not escape this galling impost. Fish had been taxed a few years before; and the young Masaniello, accustomed, in the exercise of his calling, to dispute with the tax collectors, had, from his fearless dealing with these universally hated functionaries, become a favourite with his own class and with the common people in general. One day when his wife, detected with contraband flour, was imprisoned and fined, he assembled a number of young men, armed them with sticks, and urged them to take advantage of the crowds at the approaching festival of the Madonna del Carmine to make a solemn and public protest against these oppressive taxes. On the 7th of July, however, some country people coming as usual to Naples to sell fruit, were compelled by the tax collectors to pay the duty beforehand. The market people revolted, and one of them, trampling the fruit under his feet, cried out indignantly that he would rather destroy his fruit than submit to such exaction. A crowd assembled, partly from curiosity, anger ensued, and the companions of Masaniello fanned the flame which soon burst forth. The agitation increased by degrees until it became general. The officials, who had prudently retreated, were now panic-struck; still the insurrection wanted a chief, and Masaniello resolved at once to seize the opportunity. He made his way among the crowd, and with a voice that drowned all other sounds, cried, "Away with the tax on fruit! death to bad rulers!" "Away with them!" shouted the multitude; "Long live Masaniello!" In a moment the infuriated mob drove off the functionaries, who were looking on in mute astonishment, burned the tax-collectors' offices, and proceeded to the royal palace to besiege the viceroy, who had, however, already taken refuge in the Castel Nuovo. The people must vent their rage on something; so Masaniello directed that the houses of the nobility should be burned, but threatened death to any who should attempt to abstract a single object from the flames. This order was blindly obeyed. The prisons were thrown open, and one Perrone, who afterwards became Masaniello's evil genius, was set at liberty, together with all the thieves and malefactors of the town. The viceroy sent a messenger, who promised everything; but Masaniello, not satisfied with simple promises, demanded the charter granted by Charles V. prohibiting the imposition of new taxes, except by a special decree from the king. A hundred thousand men were now at the command of the intrepid fisherman, whom they followed and promptly obeyed. A perambulating throne or platform was erected, consisting of a rough high-raised dais, placed on a waggon drawn by four strong horses. On this he sat, sword in hand, the red cap of the fisherman on his head, and dressed in the mean garb of his calling. This simplicity increased the enthusiasm of his followers, and Masaniello found himself the animating soul of thousands. The Cardinal Filomarini, Archbishop of Naples, came as a mediator from the viceroy, and was received with marks of respect. Hopes were entertained that the insurrection would be checked, when the nobles, headed by the Duke of Monteleone, and his brother Prince Caraffa, assembled 200 brigands, and charged them to assassinate Masaniello. Two hundred shots were fired at him while seated on his throne, but, by an extraordinary chance, not one reached him. This inflamed the popular fervour to a degree of fanaticism, while superstition and ignorance were ready with their marvellous explanations. The assassins were seized and executed. None were spared,—not even those who denounced their instigators. Two hundred heads, fixed on poles, now bristled round the throne-like erection on which Masaniello, the people's idol, sat. The two noblemen were pursued, but the duke made his escape; while the prince, having fallen into the hands of the mob, was beheaded and quartered; his head, bearing the inscription "*Giuseppe Caraffa ribelle e traditore della patria*," being placed conspicuously among the others. Judicial, regal, administrative powers were all now centred in Masaniello's absolute and single hand. He ordered the nobles to be disarmed, and the people to receive each man a sword, a musket, ample ammunition, and provisions. He established a police, and decreed that all judgments should be referred to him, on which he gave prompt and impartial verdicts.

At last, through the intervention of the Archbishop of Naples, he consented to treat with the viceroy. He now began to despise his red cap and fisherman's dress, and assumed a gaudy attire glittering with silver and gold. The people were amazed when they saw him, thus adorned, head a cavalcade, equally splendid, on his way to the church of the Madonna del Carmine to negotiate a treaty with the viceroy. He styled himself "Capo del Popolo," and with this attribute he altered, modified, and rescinded, as he thought proper; none daring to oppose him. Finally the principal terms were settled:—*1st*, The total abolition of all the taxes imposed since the time of Charles V.; *2d*, Absolute equality of political rights among all classes of citizens; *3d*, General amnesty to all who had taken part in the insurrection; *4th*, That the Neapolitan people should remain armed till the ratification of the treaty by his Catholic Majesty the King of Spain. He then exacted an oath from the Duke d'Arcos, and turning to the people, declared his mission accomplished, his desires fulfilled, and that henceforth he would follow his trade as a fisherman. Having said these words, he threw off his rich attire, fell at the feet of the viceroy, professed allegiance to the king, love to the people, devotion to his country, and rejected all proffered rewards. This imposing scene called forth the deafening shouts of the multitude that thronged the church, who begged him to retain the authority he had for several days exercised so successfully. The Duke d'Arcos showed him the greatest respect, praised his skill in statesmanship, and, to celebrate the restoration of peace, invited him to a solemn banquet at the royal palace. Masaniello's star now began to wane. His conduct at the banquet was boastful and extravagant, some say showing signs of an unsound mind, caused by overjoy at his success, or, as other historians affirm, by a poisoned drink given him by the viceroy. Masaniello, now arrogant, overbearing, and arbitrary to his fellows, lost that simplicity which had made him their idol. At the close of the fourth day of his power, two hundred thousand men would have given their life for him; on the eighth day there were as many disaffected. The Duke d'Arcos, who had been plotting to bring about this state of things, seeing the moment had now arrived to get rid of the spirited tribune without danger to himself, on the 16th of July placed four men in ambush. They fired upon the unfortunate leader, who fell down dead. Hated as much as he had been loved, his body was insulted even by his old friends. The hired assassins, emboldened by this feeling, showed their zeal by severing his head from his body, and holding it by the hair, presented it to the viceroy, who ordered it to be thrown into the castle moat. One day, however, had scarcely passed when a more natural feeling returned. The greater part of the people deplored the effects of sudden ambition on the mind of their chief, pitied him, wept for his untimely fate, and were ashamed they had not taken immediate revenge on his murderers. His body was exhumed, and with the head joined to it, was placed on a bier, covered with a regal purple robe, a crown of laurel on the brow, a sceptre in the right hand, and amid the solemn tolling of all the church bells it was carried in procession through the twelve districts of the town, followed, according to one historian, by 400,000 people. The viceroy, by a stroke of policy, sent his own pages in state, and ordered that funeral honours should be rendered to the "Capo del Popolo," whose body, after having lain in state several days, was finally buried with all the pomp reserved to men of the highest rank. The Duke d'Arcos, when the popular excitement had subsided, was perfidious enough to persecute numbers of the lower orders who had taken part in the revolution, thus causing the memory of Masaniello to be more than ever regretted. To this day he is held in high esteem by the liberal party of the *lazzaroni* of Naples, who regard him as the glory of their class, and the standard of popular heroes.

The most complete account of this remarkable episode in history was contained in a manuscript of the Padri Filippini dell' Oratorio in Naples. The monks consented only lately to publish this interesting document. It is entitled *Diario di Francesco Capecelatro contenente la storia delle cose avvenute nel Reame di Napoli negli anni* 1647–50, *ora par la prima volta messo a stampa, etc dal Marchese Angelo Granito*, Napoli, 1854, presso G. Nobile. (E. F.)

MASBATE, one of the Philippine Islands, in the Indian Archipelago, situated to the S. of Luzon and W. of Samar, in the middle of the Bisaya Sea. The shape of the island is triangular; it is about 70 miles in length by 20 in average breadth; and its area is computed at 1225 square miles. It consists for the most part of rocky mountains, with only a small portion of cultivated land, and is very thinly populated. The principal article of produce is rice. The island contains the harbours of Barreras and Catayugan.

MASCALI NUOVO, a town in Sicily, province of Catania, is situated at the foot of Mount Etna, on a small river about 2 miles from the sea, and 18 miles N.N.E. of Catania. The town is ill built, and, though formerly flourishing, is now in a declining condition. Fishing, however, is still actively carried on; and there is some trade in lime, lava, timber, corn, wine, and fruits. The surrounding country is fertile, and contains many thriving villages. A little to the N.W. stands the village of Mascali Vecchio. There have been found here many curious remains of antiquity, especially of the Saracenic period. Pop. about 4000.

MASCARA, a town of Algeria, province of Oran, pleasantly situated on the S. slope of the Atlas range, 45 miles S.E. of Oran. It was formerly the residence of Abd-el-Kader, and was strongly fortified and defended by a castle. It was taken and burnt by the French in 1835, and was again taken by them in 1841, since which time it has remained in their possession. It has been much improved since it came into the hands of the conquerors, and is now strongly garrisoned. Pop. (1851) 4915, of whom 3210 were natives.

MASCHERONI, Lorenzo, an Italian mathematician, was born at Bergamo in 1750. Intended for the church, he devoted his attention to the classical languages, and studied so successfully, that at the age of eighteen he was appointed professor of humanity in the university of his native city. From this situation he was promoted to the chair of Greek at Pavia. Chancing, however, in his twenty-seventh year, to take up a book on mathematics, he conceived so intense an enthusiasm for that science, that he forthwith renounced all other studies for its sake. His former success attended him in this new pursuit, and he was soon appointed professor of geometry in the college of Mariano at Bergamo. In 1795 he published at Milan his *Geometry of the Compass*, a work which secured for him the patronage of Bonaparte. Mascheroni, priest though he was, became a zealous promoter of the revolution that attended the invasion of Italy by the French. Accordingly he was elected a member of the legislative body of the Cisalpine Republic. In 1798 he was sent to Paris to study the French system of weights and measures, and to apply it to Italy. His zeal, however, in discharging this duty, was the cause of an illness which closed his career in July

1800. Mascheroni's chief work, *The Geometry of the Compass*, was translated into French by M. Carette, 8vo, Paris, 1798. (See *Fifth Dissertation*, § i.)

MASERES, Baron. (See *Fifth Dissertation*, p. 709.)

MASHAM, a market-town of England, North Riding of Yorkshire, on the Ure, 16 miles S.S.E. of Richmond. It has a parish church in the early English style, surmounted by a lofty spire, several Dissenting places of worship, a grammar school, mechanics' institute, a library, a literary and several benevolent societies. The inhabitants are chiefly employed in the manufacture of woollen stuffs and in the spinning of flax. Pop. (1851) 1139.

MASINISSA, a celebrated African prince, son of Gala, king of the Numidian tribe of the Massyli, was born about 239 B.C. Receiving his education at Carthage, and thus becoming interested in the welfare of that city, he incited his father in 213 B.C. to form a league with the Carthaginians. In the same year, accordingly, Masinissa, at the head of a troop of Numidian cavalry, sailed for Spain, and served most devotedly in the war against the Romans. But the check which the Punic fortunes received at Silpia in 206 B.C. shook his fidelity, and he resolved to pass over to the Romans on the first safe opportunity. This resolution was strengthened by the generosity which his nephew Massiva had experienced from Scipio, and probably also by the intelligence that Sophonisba, the beautiful daughter of Hasdrubal, to whom he had been betrothed, was about to be wedded to Syphax, the prince of the Numidian tribe of the Massæsyli. Meanwhile an event had occurred in Africa that accelerated the defection of Masinissa. The crown of his native country, which, after the death of his father Gala, had passed in rapid succession to his uncle Œsalces, and his cousin Capusa, was seized at this time in the name of an infant brother of the latter by Mezetulus. On hearing of this usurpation, Masinissa crossed to Africa, rallied around his standard the old soldiers of his father, defeated Mezetulus in a pitched battle, and forced him to flee, along with his royal ward, into the dominions of Syphax. No sooner, however, was Masinissa seated on his ancestral throne, than he recalled the two fugitives, and by his favours disarmed their hostility. But a more formidable foe immediately appeared in the person of Syphax. Instigated and backed by the Carthaginians, that prince invaded the Massylian territories, and annihilated in quick succession those armies which had been hastily mustered to oppose him. Thus stripped of his sovereignty, and driven from his kingdom, Masinissa was obliged to skulk with a few followers near the sea-shore, until the landing of Scipio in 204 B.C. gave him the opportunity which he had for some time wished, of identifying his cause with that of the Romans. He joined the invaders with a part of his shattered forces, and by his active fidelity, and his knowledge of the habits of the enemy, contributed in no small degree to the two victories gained over Hasdrubal and Syphax. On the capture of Cirta, the metropolis of the Massæsyli, Masinissa obtained possession of Sophonisba, the wife of Syphax, and, with her own consent, married her. But Scipio severely censured his marriage with so determined a foe of the Romans; and Sophonisba, by the advice of her newly-espoused husband, poisoned herself to escape the ignominy of falling into the power of her enemies. The grief of Masinissa for this untoward event was allayed by his reinstalment into the sovereignty of the Massylians. From the quiet possession of his power, however, he was soon summoned by the arrival of Hannibal in Africa. In the decisive conflict of Zama which followed (202 B.C.), he made a brilliant charge at the head of his Numidian horse, drove the cavalry of Hannibal from the field, and was thus the first to turn the tide of battle against the Carthaginians. For this important service he was rewarded in the following year with the greater part of the kingdom of Syphax. Firmly fixed in his possessions, with the title of King of Numidia, Masinissa now devoted his attention to the organization of his government and the improvement of his people. Yet at times his ambitious spirit, and his reliance upon the powerful support of Rome, incited him to provoke by aggressions the humbled Carthaginians. In all these disputes the Romans acted as mediators, and uniformly favoured the Numidian king. At length in 150 B.C. the Carthaginians, indignant at the intrigues which Masinissa had been carrying on against the welfare of their city, commenced acts of hostility. Masinissa accordingly marched into their territories, and though deserted by several of his chiefs, he adroitly circumvented the enemy, and forced them to capitulate. He died in 148 B.C., at the age of ninety, while Roman ambassadors were on the way to his palace to demand reinforcements for the third Punic war. In accordance with his dying request, his kingdom was divided between his three sons, Micipsa, Gulussa, and Mastanabal.

Masinissa displayed all the qualities that render a prince the favourite of semi-barbarian subjects. Not destitute of skill in strategy, he also possessed a dauntless valour in action, and an unshaken magnanimity under reverses. He shared the hardships and fare of the meanest soldier; and till within a short time before his death, he underwent with surprising agility all the warlike exercises of youth. His attempts to civilize his people were highly praiseworthy.

MASKELYNE, Nevil, a most industrious and accurate astronomer, born in London on the 6th of October 1732, was the son of Mr Edmund Maskelyne, a gentleman of respectable family in Wiltshire.

At the age of nine he was sent to Westminster School, and continued to apply with diligence to the usual pursuits of that place, until the occurrence of the great solar eclipse of 1748, which made a strong impression on his mind, and was the immediate cause of his directing his attention to astronomy, and beginning with great ardour the study of the mathematics as subservient to that of astronomy. It is remarkable, that the same eclipse is said to have made an astronomer of Lalande, who was only three months older than Maskelyne. He soon afterwards entered as a member of Catherine Hall, Cambridge, but in a short time removed to Trinity. He took the degree of Bachelor of Arts with great credit in 1754, and proceeded regularly afterwards through the succeeding stages of academical rank in divinity. He was ordained in 1755 to a curacy at Barnet, and the next year he obtained a fellowship at Trinity. In 1758 he was elected a fellow of the Royal Society; having previously become intimate with Dr Bradley, and determined to make astronomy the principal pursuit of his life, feeling its perfect compatibility with an enlightened devotion to the duties of his own profession.

In 1761 he was engaged by the Royal Society to undertake a voyage to St Helena in order to observe the transit of Venus. He remained ten months in that island, but the weather prevented his observing the transit to advantage; and the faulty attachment of the plumb-line of his quadrant, which was of the construction then usually employed, rendered his observations on the stars less conclusive with respect to annual parallax than he had expected. His voyage was, however, of great use to navigation, by promoting the introduction of lunar observations for ascertaining the longitude; and he taught the officers of the ship which conveyed him the proper use of the instruments, as well as the mode of making the computations.

He performed a second voyage in 1763 to the island of Barbadoes in order to determine the rates of Harrison's watches, and also to make experiments with Irvine's marine chair on board of the "Princess Louisa," Admiral Tyrrel; acting at the same time as chaplain to the ship. The chair he found of very little use for observing the eclipses of Jupiter's satellites; and the maker of the chronometers was not satisfied with his report of their performance, fancying that he was too partial to the exclusive employment of lunar observations for determining the longitude. The liberality of the British government, however, bestowed on Harrison the whole reward that he claimed; and Maskelyne having been appointed to the situation of astronomer-royal, and having thus become a member of the Board of Longitude, was extremely active in obtaining a few thousand pounds for the family of Professor Mayer, who had computed lunar tables, and a compliment of L.300 for Euler, whose theorems had been employed in the investigation.

The merits of Mayer's tables having been fully established, the Board of Longitude was induced to promote their application to practical purposes by the annual publication of the *Nautical Almanac*, which was arranged and conducted entirely under Maskelyne's direction for the remainder of his life. He was also actively employed, without any other motive than the love of science and of his country, in almost every decision which was required of the Board of Longitude; and he had to give his opinion of the merits of an infinite number of fruitless projects which were continually submitted to his judgment. He must of course have made many enemies amongst the weak and illiberal; but the universal impartiality and the general accuracy of his determinations were acknowledged by all candid persons; and it must be admitted, that the longitudinarys peculators of Great Britain in those days submitted to discouraging remarks from persons in authority, with wonderful fortitude and with great personal civility.

During the forty-seven years that he held the situation of astronomer-royal, he acquired the respect of all Europe by the diligence and accuracy of his observations, which he never neglected to conduct in person whenever it was in his power, and he required only one assistant. The French had a handsome building to amuse the public by its exterior magnificence; but the establishment of the observers was never arranged in so methodical a manner as that of the English national observatory, and the fruits of their labours were never systematically made public, the attempt which was once made by Lemonnier in his *Histoire Céleste* having been interrupted and discontinued. Dr Maskelyne, on the other hand, obtained leave from the British government to have his observations printed at the public expense under the direction of the Royal Society, who are the legal visitors of the observatory, appointed by the royal sign manual. The early observations of Flamsteed and of Bradley were considered as private property. Flamsteed published his own, and Bradley's were very liberally bought of his family, and afterwards printed by the university of Oxford, who are still as liberal in bestowing them where they are likely to be employed for the benefit of science. Flamsteed was the astronomer-royal from 1690 to 1720, then Halley to 1750, Bradley to 1762, and Bliss to 1765, when Maskelyne was appointed. He took his doctor's degree in the year 1777.

He made several improvements in the arrangement and employment of the instruments, particularly by enlarging the slits through which the light was admitted; by making the eye-glass of his transit telescope moveable to the place of each of the wires of the micrometer; and, above all, by marking the time to tenths of a second, which had never been attempted before, but which he found it practicable to effect with surprising accuracy, as the comparison of the observations at the different wires sufficiently demonstrated.

The object of his expedition to Schchallien is well known. Bouguer had made an unsuccessful attempt to measure the attraction of a mountain in South America, and had been obliged to conclude that the mountain was hollow, in consequence of the eruption of a volcano, the attraction being too little sensible. Dr Maskelyne's results, on the other hand, as computed by Dr Hutton, made the mountain more dense than could well have been expected; but those who are acquainted with the difficulty of executing astronomical measurements without an error of a single second of space, will be ready to allow that the deviation of 5″ or 6″, attributed to the effect of the mountain, is liable to a much greater proportional uncertainty than the results obtained by Mr Cavendish with the apparatus invented by Mr Michell. (See CAVENDISH.) The geodesical operations which were soon afterwards performed, with his concurrence and assistance, for determining the relative situations of Greenwich and Paris, were equally creditable to the English artists who constructed the instruments, and to the astronomers and geographers who made the observations with them; and, even by the confession of their rivals, they excelled everything that had ever been effected in former measurements of the same kind.

As no man had done more for practical astronomy than Dr Maskelyne, so there was none whose merits were more justly appreciated. He made every astronomer his friend, as well by his personal kindness as by his professional labours; and he obtained the rare distinction of being made one of the eight foreign associates of the French Academy of Sciences. His example and encouragement contributed to the establishment of several private observatories, which must always be, if not immediately, at least remotely, beneficial to astronomy, as tending to promote the improvement of instruments and of the methods of employing them.

He was modest, and somewhat timid in receiving the visits of strangers; but his usual conversation was cheerful, and often playful, with a fondness for point and for classical allusion. He inherited a good paternal property, and he obtained considerable preferment from his college; he also married, somewhat late in life, the sister and coheiress of Lady Booth of Northamptonshire. His sister was the wife of Robert Lord Clive and the mother of the Earl of Powis. He died on the 9th of February 1811, in his seventy-ninth year, leaving a widow and an only daughter.

Dr Maskelyne's first communication to the Royal Society is, A Proposal for discovering the Annual Parallax of Sirius. (*Phil. Trans.* li., 1760, p. 889.) It is founded on Lacaille's observations made at the Cape of Good Hope, which appeared to indicate a maximum amounting to 8″. 2. A Theorem for Spherical Aberration (lii., 1761, p. 17), dated from the "Prince Henry," St Helen's Roads, the calculation being adapted to the object-glasses of achromatic telescopes. 3. The next article (p. 21) is a letter from Lacaille recommending that he should make observations at St Helena on the lunar parallax, and remain some time in the island for that purpose, and promising, on his own part, to make corresponding observations. It is followed by a letter from Maskelyne proposing some additional joint observations. 4. Observation of the Transit of 1761 (p. 196). The sun was lower than had been expected, and the instant of contact uncertain, from a tremulous motion in the apparent discs. 5. Observations on a Clock of Shelton (1762, p. 434), giving the proportion of ·99754 to 1 for the comparative force of gravity at Greenwich and at St Helena. 6. A Letter on the Mode of observing and computing Lunar Distances (p. 558), dated from St Helena; the first demonstration of the practicability and utility of the method. He found the error of observation not to exceed half a degree of longitude, an error which was very strangely suffered to remain as a fair allowance for the uncertainty of observation in the acts for encouraging the perfection of the lunar tables, subsequently repealed. 7. On the Tides at St Helena (p. 586); observations made in a harbour for about two months. 8. Note to Lalande (p. 607) on Lunar Distances and Occultations. 9. Rules for correcting Lunar Distances (*Phil. Trans.*, 1764, p. 263); a demonstration of the rules before published in the *Transactions* and in the *British Mariner's Guide*. 10. Remarks on the Equation of Time (p. 336); correcting a mistake of Lacaille and an inadvertence of Lalande, and giving a formula, which, though not geometrically perfect, is abundantly accurate for all practical purposes. 11. Astronomical Observations made at St Helena (p. 348). The observations for determining the lunar parallax were too few to afford a satisfactory result. The author suggests that the figure of the earth might be ascertained by repeated and comparative observations of the apparent distance of the moon from neighbouring stars. 12. Observations made at Barbadoes (p. 189), especially on Jupiter's satellites. 13. Introduction to two Papers of Mr Smeaton (lviii., 1768, p. 154); the one on the menstrual parallax, the other on observing stars out of the meridian. 14. Introduction to the Observations of Mason and Dixon (p. 270). 15. Conclusion respecting the Length of a Degree (p. 323, 325). Mr Charles Mason had been sent with Mr Dixon to observe the transit of 1761 at Bencoolen, but their voyage was interrupted by accidental circumstances, and they made their observations at the Cape of Good Hope with tolerable success. They then proceeded to join Maskelyne at St Helena, and to assist in his operations there. They were afterwards engaged by Lord Baltimore and Mr Penn to determine the boundaries between Maryland and Pennsylvania; and having completed their survey, they suggested to the council of the Royal Society the eligibility of measuring a degree in the country bordering on the Delaware and the Chesapeake. Their proposals were readily accepted, and the results of their measurement are here recorded. Dr Maskelyne afterwards employed Mason in his operations on Schehallien, in computing Bradley's observations, and in improving Mayer's tables by a comparison with them; but he was so fearful of admitting any empirical corrections not founded on the most general principles, that he would not allow some of the equations discovered by Mason to be introduced into the computation of the *Nautical Almanac* until M. de Laplace had proved their dependence on the theory of gravity. Lalande tells us that Mason was dissatisfied because he did not receive a public reward for the success of his labours; but he was, in fact, little more than the agent of Maskelyne and of the Board of Longitude; and he was fairly repaid for the time and labour which his computations had required. Delambre says that he died in Pennsylvania in 1787. Dixon is said to have been born in a coal mine, and to have died at Durham in 1777. 15. Postscript respecting French and English Measures (p. 325). The result of this comparison agrees remarkably well with the later measurement of Pictet, Prony, and Captain Kater. 16. Observation of the Transit of 1769, made at the Royal Observatory (p. 355). 17. Eclipses and Occultations, 1769 (p. 399), chiefly for the longitude of Glasgow. 18. On the Use of Dollond's Micrometer, 1771 (p. 536). On the application of the divided object-glass micrometer to determining differences of right ascension and of declination, especially in the case of transits; a part of the instructions sent with the observers to the South Seas. 19. On the Adjustment of Hadley's Quadrant, 1772 (p. 99), especially for the back observation, and to insure the parallelism of the glasses. 20. Deluc's Rule for Measuring Heights, 1774 (p. 158), adapted to English measures, and rendered somewhat more convenient. 21. Observations at Greenwich and in America compared (p. 184, 190). 22. Proposal for Measuring the Attraction of a Hill, 1775 (p. 495); read in 1772. 23. Observations made on Schehallien (p. 500); a paper which obtained its author the honour of a Copleian medal. Mason had been sent to examine the hills of Scotland, and had recommended Schehallien; the funds were supplied by the remainder of the royal grant for observing the transit of Venus. Mr Reuben Burrow and Mr Menzies were principally employed in assisting the astronomer-royal in his observations and surveys; and Dr Hutton afterwards made the necessary computations for determining the attraction of the mountain. 24. Description of a Prismatic Micrometer, 1777 (p. 799), consisting of one or more prisms sliding in the axis of the telescope, and resembling in its operation that of Rochon, which has in great measure superseded it. 25. On the Longitude of Cork, 1779 (p. 179); observations for correcting the computed times of the eclipses of Jupiter's satellites. 26. On the Comet expected in 1789 (*Phil. Trans.*, 1786, p. 426); supposing those of 1532 and 1661 to be the same. (See MECHAIN.) 27. On the Latitude and Longitude of Greenwich, 1787 (p. 151); with Cassini's Memoir on its uncertainty, which he states as amounting to 11″ in longitude, and 15″ in latitude. Dr Maskelyne, however, shows that it is confined within much narrower limits, though he approves of the object of the memoir in promoting a survey. 28. On a Difficulty in the Theory of Vision, 1789 (p. 256). This paper sufficiently proves that Euler was mistaken in thinking the eye achromatic; and that any appearance of colour which it could produce, according to the common laws of refraction, would be imperceptible in ordinary circumstances. But that there are circumstances under which such appearances may be observed, was afterwards shown by Dr Young and Dr Wollaston. 29. Account of an Appearance of Light on the Dark Part of the Moon, 1793 (p. 429); seen by Mr Wilkins and by a servant of Sir George Booth, and supposed to have arisen from a volcano. 30. Observations of the Comet of 1793 (*Phil. Trans.*, 1794, p. 55); discovered by the Rev. E. Gregory of Langar, in Nottinghamshire. 31. The earliest of Maskelyne's separate publications was the *British Mariner's Guide*, London, 763, 4to,—a small volume, which has become scarce, having been superseded by later works. 32. The *Nautical Almanac* and *Astronomical Ephemeris* for 1767 appeared in 1766; and the publication was regularly continued upon the same plan for some time, by the computers and comparers whom Dr Maskelyne had trained by his instruction and example. His successor in the observatory, though admirably qualified to equal, and perhaps to excel him in the practical department, had it not in his power to devote so much of his attention to the publication as Dr Maskelyne's paternal affection for a child of his own had induced him to bestow on it; and the Board of Longitude was very liberally furnished by government with the means of obtaining some further assistance to supply his place. 33. Tables requisite to be used with the *Nautical Almanac*, London, 1766, 1783, 1802, 8vo,—since partly superseded by Professor Lax's new edition. 34. The volume of Selections, from the additions that have been occasionally made to the *Nautical Almanac*, London, 1812, 8vo, contains several papers of Dr Maskelyne; for example, Instructions relating to the Transit of Venus in 1769, N. A. 1769; Elements of Lunar Tables, and Remarks on Hadley's Quadrant, N. A., 1774; Advertisement of the Comet expected in 1788, N. A., 1791; and on the Disappearance of Saturn's Ring in 1780, N. A., 1791. 35. The Astronomical Observations made at Greenwich, from 1765 to 1811, were published annually in folio, making 3 vols., and part of a fourth, London, 1774. They are allowed to constitute the most perfect body of astronomy in detail that was ever presented to the public. The first volume contains a variety of useful tables, accompanying the observations for 1772, and principally serving for the correction of the places of the stars, and for facilitating the solution of other astronomical problems. Many of them have been reprinted in Vince's *Astronomy*, but in some cases without the necessary explanations. (T. Y.)

(Kelly in Rees's *Cyclopædia*, art. "Maskelyne;" Chalmers, *Biographical Dictionary*, xxi., 8vo, London, 1815; Delambre, *Mém. de l'Inst. des Sc.*, 1811, H. lix.; and *Biographie Universelle*, xxvii., 8vo, Paris, 1820.)

MASON, WILLIAM, an English poet, born in the year 1725, was the son of a clergyman who held the living of Hull. He was educated at Cambridge, and was admitted a fellow of Pembroke College in 1747. He became rector of Aston in Yorkshire, and chaplain to his Majesty; and was subsequently made precentor and canon residentiary of the cathedral of York. His monody to the memory of Pope; and *Isis*, an elegy; added to his fame, which was still further increased by his dramatic poems of *Elfrida* in 1752, and *Caractacus* in 1759, written after the manner of the ancients. He published a small collection of odes in 1756, intended as an imitation of his friend Gray, which afforded Colman and Lloyd effective subjects for clever parodies. In 1763 he produced some elegies marked by simplicity of language and noble sentiment. In point of morality he may justly be considered as the purest of poets, and one of the warmest friends of civil liberty. The first book of his *English Garden* made its appearance in 1772, being a dull didactic poem in blank verse, of which the fourth and last book was printed in the year 1781. In 1775 he published the poems of Gray, to which he prefixed memoirs of his life and writings; and in 1783 he produced an elegant poetical translation of Dufresnoy's Latin poem on the art of painting; besides *An Historical and Critical Essay on English Church Music*. An additional volume of his poems was given to the world in 1797, consisting of miscellaneous pieces, the revised productions of his youth, and the effusions of his old age. He died in April 1797, at the age of seventy-two. A tablet has been placed to his memory in the Poets' Corner in Westminster Abbey.

MASONRY. See STONE MASONRY.

MASONRY, *Free*, denotes the rule or system of mysteries and secrets peculiar to the society of free and accepted masons.

One of the first objects of man, in a rude state of being, is to screen himself and his family from the heat of the tropical sun, from the inclemency of the polar regions, or from the sudden changes of more temperate climates. If he has arrived at such a degree of improvement as to live under the dominion of a superior, and under the influence of religious belief, the palace of his king and the temple of his gods will be reared in the most magnificent style which his skill can devise and his industry accomplish.

Architecture is accordingly entitled to a very high position amongst the other arts. It is itself the parent of many separate professions, and requires a combination of talent and an extent of knowledge for which few other professions have, for the most part, any occasion. There is some foundation in the very nature of architecture for those extraordinary privileges to which masons have always laid claim, and which they have almost always possessed; and there appears also to be some foundation for that ancient and respectable order of free masons whose history we are now to investigate, without, at the same time, revealing those ceremonial observances which are only known to the brethren of the order.

Free masonry is an ancient and respectable institution, embracing individuals of every nation, religion, and condition in life. In order to confirm this institution, and attain the ends for which it was originally formed, every candidate comes under a solemn engagement never to divulge the mysteries of the order, nor communicate to the uninitiated the secrets with which he may be intrusted, and the proceedings and plans with which the fraternity may be engaged. After the candidate has undergone the necessary ceremonies, and received the usual instructions, appropriate words and significant signs are imparted to him, that he may be enabled to distinguish his brethren of the order from the uninitiated vulgar, and convince others that he is entitled to the privileges of a brother, should he be visited by distress or by want in a distant land. If the newly-admitted member be found qualified for a higher degree, he is promoted, after due intervals of probation, till he has received that masonic knowledge which enables him to hold the highest offices of trust to which the fraternity can raise its members. At regular and appointed seasons convivial meetings of the fraternity are held, in lodges constructed for this purpose, when all distinctions of rank and differences in religion and politics are forgotten. Every one strives to give happiness to his brother; and all seem to recollect, for once, that they are sprung from the same origin, possessed of the same nature, and destined for the same end. Respecting the origin and tendency of this institution, opinions differ. Whilst a certain class of men have represented it as coeval with the world, others have maintained that it was the invention of English Jesuits, to promote the views of that intriguing and dangerous association. Some have laboured to prove that free masonry arose during the crusades; that it was a secondary order of chivalry; that its forms originated from that warlike institution, and were adapted to the peaceful, orderly habits of scientific men. Mr Clinch (*Anthologia Hibernica*, 1794) has attempted, with considerable ingenuity and learning, to deduce its origin from the institutions of Pythagoras. M. Barruel (*Memoirs of Jacobinism*, vol. ii.) supposes it to be a continuation of the society of knights templars; whilst others have imputed its origin to secret associations, averse to the interests of true government, and pursuing the chimerical project of levelling the distinctions of society, and freeing the human mind from the obligations of religion and morality. But without adopting any of these untenable opinions, we may at all events establish its claim to a comparatively early origin.

The desire for pomp and ceremony displayed at an early period by the Roman Catholic priests in the exercise of their religion, introduced a corresponding desire for splendid monasteries and magnificent cathedrals. In order to encourage the profession of architecture, the pontiffs of Rome, and the other potentates of Europe, conferred on the fraternity of free masons the most important privileges, and allowed them to be governed by laws, customs, and ceremonies peculiar to themselves. The association was composed of men of all nations, of Italian, Greek, French, German, and Flemish artists, who were denominated free masons, and who, travelling from one country to another, erected those elegant churches and cathedrals which men still admire. The government of this association was remarkably regular. Its members lived in a camp of huts, reared beside the building in which they were employed. A surveyor or master presided over and directed the whole. Every tenth man was called a warden, and overlooked those who were under his charge; and such artificers as were not members of this fraternity were prohibited from engaging in those buildings which free masons alone had a title to rear (Wren's *Parentalia*, p. 306, 307. Henry's *Hist. of Great Brit.*, vol. viii., p. 273). In 1140 A.D., wherever the Roman Catholic religion was taught, the meetings of free masons were sanctioned and patronized. That free masonry was first introduced into Scotland by those architects who built the abbey of Kilwinning, is manifest, not only from authentic documents, by means of which the existence of the Kilwinning lodge has been traced back as far as the end of the fifteenth century, but also by other weighty collateral arguments. (*Statis. Ac. of Scot.*, vol. xi.) When we consider that the association of free masons monopolized the building of religious structures in Christendom, we are warranted to conclude that those numerous and elegant ruins which still adorn various parts of Scotland were erected by foreign masons, who introduced into this island the customs of their order.

It was probably about this time, also, that free masonry was introduced into England; but whether the English received it from the Scottish masons at Kilwinning, or from other brethren who had arrived from the continent, there are now no means of determining. The masonic fraternity in England, however, maintain that St Alban, the protomartyr, who flourished about the end of the third century, was the first who brought masonry to Britain; that the brethren received a charter from King Athelstane, and that his brother Edwin summoned to meet at York all the lodges which formed the first grand lodge of England in A.D. 926. But these assertions are inconsistent with several historical events which rest upon indubitable evidence. (Plot's *Nat. Hist. of Staffordshire*, chap. viii.)

After the establishment of the Kilwinning and the York lodges, the principles of free masonry were rapidly diffused throughout both kingdoms, and several lodges were erected in different parts of the island. As all these derived their existence and authority from the two mother lodges, they were likewise under their jurisdiction and control; and when any differences arose connected with the art of building, they were referred to the general meetings of the fraternity held at Kilwinning and at York. In this manner did free masonry flourish for a while in Britain after it was completely abolished in every other part of the world. But even here it was doomed to suffer a long and serious decline, and to experience successive alternations of advancement and decay. And although, during several centuries after the importation of free masonry into Britain, the brethren of the order held their public assemblies, and were sometimes prohibited from meeting by the interference of the legislature, it can scarcely be said to have attracted general attention till the beginning of the seventeenth century. There being now no scarcity of architects, the very reason which prompted the church to protect the fraternity ceased to exist; they therefore withdrew from them that patronage which they had spontaneously proffered, and denied them even the liberty of holding their secret assemblies. But these were not the only causes which produced such a striking change in the conduct of the church towards the masonic order. As we have already stated, the spirit of free masonry was hostile to the principles of the church of Rome. The intention of the one was to enlighten the mind; the object and policy of the other were to retain it in ignorance. When free masonry flourished, the power of the church must have decayed. The jealousy of the latter was therefore aroused; and, as the civil power in England and Scotland was almost always in the hands of ecclesiastics, the church and the state were combined against the principles and the practice of free masonry. But besides the causes here specified, the domestic and bloody wars which convulsed the two kingdoms from the thirteenth to the seventeenth century conspired, in a great degree, to produce that decline of the fraternity for which we have been attempting to account. Yet notwithstanding these unfavourable circumstances, free masonry seems to have flourished, and attracted the attention of the public in the reign of Henry VI., who, when a minor, ascended the throne of England in 1422. In the third year of his reign, indeed, the parliament passed a severe act against the fraternity, at the instigation of Henry Beaufort, bishop of Winchester, who was then intrusted with the education of the young king. They enacted that the masons should no longer hold their chapters and annual assemblies; that those who summoned such chapters and assemblies should be considered as felons; and that those who resorted to them should be subjected to fine and imprisonment (3 Henry VI., cap. 2, A.D. 1425). But it would appear that this act was never put in execution; for, in the year 1429, about five years after it was framed, a most respectable lodge was held at Canterbury under the patronage of the archbishop himself. When King Henry assumed the government, he not only permitted the order to hold their meetings without molestation, but even honoured the lodges by his presence as a brother. Before he was initiated, however, into the mysteries of the order, he seems to have examined, with scrupulous care, the nature of the institution, and to have perused the charges and regulations of the fraternity, which had been collected from their ancient records.

Henry VII. became grand master of the order, and was succeeded in this office by the celebrated Cardinal Wolsey. In the reign of Queen Elizabeth an armed force was sent to break up the grand lodge at York, but some of the chiefs being induced to join the order, a report was made to the Queen, which led to the liberation of the masons from all future molestation. Several of the kings of England were subsequently grand masters of the order,—though during the reign of James II. it was much neglected; but on the accession of William III. it was revived under his majesty's auspices, who confirmed the choice of the brethren when Sir Christopher Wren was made grand master. It was not, however, until 1717 that the first regular grand lodge was formed in London, with power to grant charters for the holding of other lodges. This grand lodge having subsequently granted charters in the district which the grand lodge of York claimed as its own, all friendly communication ceased between them. Several attempts were made to heal the differences, and bring about a union of the two lodges, but they all failed until the year 1813, when H R. H. the Duke of Kent being grand master of the York or Athol masons, and H. R. H. the Duke of Sussex grand master of the London masons, that desirable end was effected. The Duke of Sussex became the grand master of the united body, which he continued to hold until his death in 1843, since which time the Earl of Zetland has presided over the order. The grand lodge of England has at this time upwards of 1000 lodges under its jurisdiction. It is possessed of very great wealth; and in addition to dispensing about L.2000 a year for philanthropic purposes at a monthly board, has given, up to the close of last year, upwards of L.21,000 to the four masonic charities, viz.—the Girls' School, established 1788; the Boys' School, established 1798; the Benevolent Fund for Aged Masons, established in 1842; and the Widows' Fund, established in 1850.

Whilst free masonry flourished in England under the auspices of Henry VI., it was making progress at the same time in the sister kingdom of Scotland. By the authority of James I. of Scotland, every grand master who was chosen by the brethren, either from the nobility or clergy, and approved of by the crown, was entitled to an annual revenue of four pounds Scots from each master mason, and likewise to a fee at the initiation of every new member. He was empowered to adjust any differences which might arise amongst the brethren, and to regulate those affairs connected with the fraternity which it was improper to bring under the cognisance of the courts of law. The grand master also appointed deputies or wardens, who resided in the chief towns of Scotland, and managed the concerns of the order when it was inconvenient to appeal to the grand master himself. In the reign of James II. of Scotland, the office of grand master was granted by the crown to William St Clair, earl of Orkney and Caithness, baron of Roslin, and founder of the chapel of Roslin. On account of the attention which this noblemen paid to the interests of the order, and the rapid propagation of the royal art under his administration, King James II. made the office of grand master hereditary to his heirs and successors in the barony of Roslin; in which family it continued till the institution of the grand lodge of Scotland. The barons of Roslin, in the capacity of hereditary grand masters, held their principal annual meetings at Kilwinning, the birthplace of Scottish masonry, whilst the lodge of that village granted constitutions and charters of erection to those brethren of the order who were anxious that regular lodges should be instituted in different parts of the kingdom. During the reigns of the succeeding Scottish monarchs, free masonry still flourished, though very little information can be procured respecting the state of the fraternity. In the records of the privy seal, however, there exists a letter, dated at Holyroodhouse, the 25th September 1590, and granted by King James VI. "to Patrick Copland of Udaught, for using and exercising the office of wardanrie over the art and craft of masonrie, over all the boundis of Aberdeen, Banff, and Kincardine, to had warden and justice courts within the said boundis, and there to minister justice." This letter proves beyond dispute that the kings of Scotland nominated the office-bearers of the order; that these provincial masters, or wardens as they were then called, administered justice in every dispute which concerned the "art and craft of masonrie;" that lodges had been established in all parts of Scotland, even in those remote, and, at that time uncivilized, counties of Aberdeen, Banff, and Kincardine.

When James VI. ascended the throne of England he seems to have neglected his right of nominating the office-bearers of the craft. In Hay's manuscript in the Advocates' Library, there are two charters granted by the Scottish masons, appointing the St Clairs of Roslin their hereditary grand masters. The former of these is without a date, but is signed by several masons who appoint William St Clair of Roslin, his heirs and successors, their "patrons and judges." The latter is in some measure a ratification of the former, and dated 1630, in which they appoint Sir William St Clair of Roslin, his heirs and successors, to be their "patrons, protectors, and overseers, in all time coming." In the year 1736, on the resignation of William St Clair as grand master, thirty-two lodges met and elected him grand master mason of all Scotland; and thus was instituted the grand lodge of Scotland.

The most remarkable event of recent times in free masonry has been the permission given by the grand master to the *Free Masons' Magazine* to publish the reports of proceedings in grand and private lodges.

MASORA, a term in the Jewish theology, signifying a work on the Bible, executed by several learned rabbis, in order to secure it from any alterations. (See PHILOLOGY, § *Hebrew Language*.)

MASQUERADE (Ital. *Mascherata*, Fr. *Mascarade*), a species of amusement, common to most civilized countries, in which persons of both sexes mask or disguise themselves, and engage in dancing, festivities, and miscellaneous conversation. Masquerades are said to have been invented by Granacci, an Italian, in the beginning of the sixteenth century. At all events they were fashionable in Italy as early as 1512, when they were introduced into England in the reign of Henry VIII., as old Hall informs us in his *Chronicle* (4to, London, 1809, p. 526). He says, "On the daie of the Epiphanie at night (1512-13,) the king (Henry VIII.) with a.xi. other were disguised, after the maner of Italie, called a maske, *a thyng not seen afore in Englande*, thei were appareled in garmentes long and brode, wrought all with gold, with visers and cappes of gold & after the banket doen, these maskers came in, with sixe gentlemen disguised in silk" (which some take for the modern *domino*) "bearyng staffe torches, and desired the ladies to daunce, some were content, and some that knewe the fashion of it refused, because it was not a thyng commonly seen. And after thei daunced and commoned together, as the fashion of the maske is, thei tooke their leaue and departed, and so did the quene, and all the ladies."

MASS, in the church of Rome, means the prayers and ceremonies used at the celebration of the Eucharist; or, in other words, in consecrating the bread and wine into the body and blood of Christ, as it is said, and offering them so transubstantiated as an expiatory sacrifice for the living and the dead. As the mass is believed by Roman Catholics to be a representation of the passion of our blessed Saviour, so every action of the priest, and every particular part of the service, is supposed to allude to the particular circumstances of his passion and death. The ceremonies and usages of the mass were first settled by Gregory the Great in the sixth century. The service consists of three parts: the offering of the elements, their consecration, and their sumption or participation by those who communicate. The language used in the mass is Latin, first employed in A.D. 394. (For the various views respecting the Eucharist and the sacrifice of the mass, see the article SUPPER.)

Nicod, after Baronius, observes that the word *mass* comes from the Hebrew *missach*, *oblatum*, or from the Latin *missa*, *missorum*, because in former times the catechumens and excommunicated persons were sent out of the church when the deacons said *Ite, missa est*, after sermon and reading of the epistle and gospel; they not being allowed to assist at the consecration. And hence the distinction of *missa catechumenorum* and *missa fidelium*.

The general division of masses consists of high and low. The first is that which is sung by the choristers, and celebrated with the assistance of a deacon and sub-deacon; low masses are those in which the prayers are merely rehearsed without singing.

There are many different or occasional masses in the Latin church, some of which have nothing peculiar but the name: such as, the masses of the saints; that of St Mary of the snow, celebrated on the 5th of August; that of St Margaret, patroness of lying-in women; that of the feast of St John the Baptist, at which are said three masses; that of the innocents, at which the *Gloria in excelsis* and the *Alleluia* are omitted, and, it being a day of mourning, the altar is of a violet colour. As to ordinary masses, some are said for the dead. At these masses the altar is put in mourning, and the only decorations are a cross in the middle of six yellow wax-lights; the dress of the celebrant and the mass-book are black; many parts of the office are omitted, and the people are dismissed without the benediction. If the mass be said for a person distinguished by his rank or virtues, it is followed with a funeral oration. They erect a *chapelle ardente*, that is, a representation of the deceased with branches and tapers of yellow wax, either in the middle of the church or near the tomb of the deceased, where the priest pronounces a solemn absolution of the deceased. There are likewise private masses said for the recovery of stolen or strayed goods or cattle, for health, for travellers, &c., which go under the name of *votive masses*. There is still a further distinction of masses, which are denominated from the countries in which they were used. Thus the Gothic mass, or *Missa Mosarabum*, is that which was used amongst the Goths when they were masters of Spain, and is still kept up at Toledo and Salamanca; the Ambrosian mass is that composed by St Ambrose, and used only at Milan, of which city he was bishop; the Gallic mass is that used by the ancient Gauls; and the Roman mass is the one used by almost all the churches in the communion of the Roman Catholic Church. The mass of the Presanctified (*Missa Præsanctificatorum*) is a mass peculiar to the Greek church, in which there is no consecration of the elements; but, after singing some hymns, they receive the bread and wine which was before consecrated. This mass is performed during the whole of Lent, excepting on Saturdays, Sundays, and the Annunciation.

MASSA DI CARRARA, or MASSA DUCALE, a town of Italy, formerly capital of the duchy of that name, is pleasantly situated near the left bank of the Frigido, about 2 miles from its mouth, and 58 S.W. of Modena. The town has several fine streets and squares, one of the latter of which is planted with orange trees; and its chief buildings are a cathedral and a palace. The manufacture of silk is carried on here, as well as a considerable trade in the fine marble which is got in the neighbourhood, and which is called Carrara marble. The duchy was, in the middle ages, for some time under the power of the Genoese; and afterwards, for several centuries, belonged to the house of Malaspina till it passed by marriage to the Genoese family of Cibo, who were at first Counts of Florentillo, but were raised by the Emperor Maximilian II. to the rank of Princes of Massa and Margraves of Carrara, and by Leopold in 1664 to that of Dukes of Massa and Princes of Carrara. In 1741 Maria Theresia Francisca, the heiress of Carrara, married Hercules Rainald, the heir of Modena; and their daughter Beatrice, Duchess of Este, married Ferdinand, Archduke of Austria, and inherited Massa and Carrara. Though dispossessed by the French in 1796, this princess was restored to her rights by the Congress of Vienna; and, on her death in 1829, the duchy was united to Modena, of which it now forms the province of Massa Carrara. Pop. of the province (1850) 56,867; of the town, 8000.

MASSACHUSETTS, one of the (eastern) United States of North America, lies between 41. 30. and 43. 52. N. Lat., and 69. 30. and 77. 30. W. Long. It is bounded N. by New Hampshire and Vermont, S. by Connecticut and Rhode Island, E. by the Atlantic Ocean, and W. by New York. It is about 190 miles in length, with an average breadth of nearly 90 miles, and an area of about 7300 square miles. Among the six New England states, Massachusetts holds a central position, and is the most important of them in several points of view. It presents a surface pleasantly undulated with hills and valleys, and is naturally divided into three distinct zones. The first, stretching along the seashore, and extending 20 miles into the interior, is a belt of marine alluvium, little elevated above the ocean, and naturally fertile only at intervals. This plain is succeeded by a fine hilly tract, which crosses the state from N. to S., and from which rivers are poured in every direction. The second or middle zone includes part of the beautiful valley of Connecticut, and is followed by the mountainous but highly fertile county of Berkshire, which comprises the

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whole western part of the state. The soil of Massachusetts is exceedingly various, comprising every description, from the most sterile to the most productive. In the eastern and south-eastern parts it is in general light and sandy, interspersed, however, with numerous fertile tracts. Towards the sea-coast on the N. it is of better quality, though not distinguished for fertility. By careful cultivation, however, both this and other parts of the state have been rendered highly productive. The middle and western regions have for the most part a strong, rich soil, excellent for grazing, and suited to most other agricultural purposes. Viewed at a glance, the surface of this state swells from the Atlantic Ocean to the hills, then sinks into the highly picturesque valley of Connecticut, and again rises into the mountainous region of Berkshire. The principal mountains are a part of the Green Mountain range, which stretches from N. to S. through the western part of the state. The most elevated summits of this ridge are Saddle Mountain, near the north-western angle of the state, and Tahconick on the western border. These mountains present a great variety of beautiful and impressive scenery, noble elevations alternating with dark green forests and pleasant well-sheltered valleys. Mount Tom and Mount Holyoke, near the Connecticut River, are striking elevations, and from their summits afford a beautiful prospect of the surrounding country. A second ridge passes through the state near its centre. The greatest elevation of this ridge is that of Wachuset, in the town of Princeton. The state abounds in small lakes, which are generally called *ponds.* The largest of these are the Assawamset and Long Ponds in Middleborough, Podunk and Quabaug Ponds in Brookfield, and the Naukheag Ponds in Ashburnham. The last-named are situated more than 1100 feet above the level of the sea, and several other ponds in the western part of the state have a still higher elevation. Massachusetts has no very large rivers wholly within its bounds. The Connecticut traverses it from N. to S., and is navigable by steamboats of 12 feet draught, above 30 miles from its mouth. The Merrimac passes out of New Hampshire into the northern division of the state, and empties itself into the sea at Newburyport. The Housatonic, Charles, Ipswich, Concord, Blackstone, Miller's, Chickopee, Deerfield, Westfield, Neponset, and Taunton, though they have short courses, are pleasant streams. Indeed no country is better provided with rivers and streams, which flow in all directions, and afford abundance of water for every necessary purpose. The rivers abound in falls admirably adapted for mill sites.

Every product which the northern states furnish, and much that is not indigenous to the soil and climate, have been naturalized in Massachusetts by skill and careful cultivation. The principal productions are Indian corn, rye, wheat, oats, barley, peas, beans, buckwheat, potatoes, hops, and hemp. Beef, pork, butter, and cheese, are abundant in most parts of the state, and of excellent quality; the county of Berkshire, in particular, is distinguished for its extensive dairies. There are fine orchards in many parts of the state. The fruits principally cultivated are apples, pears, quinces, plums, cherries, and currants. Peaches are also cultivated to a considerable extent, but they are generally of an inferior quality to those produced further south,—the principal towns in the state being chiefly supplied with that delicious fruit from New York and New Jersey. Great quantities of cider are annually made, and this formerly constituted the common beverage of the majority of the inhabitants.

There are several valuable mines in Massachusetts. Bog-iron ore is found in several parts, and there are many establishments for working it. In Southampton, Hampshire county, there is a lead mine, to which a subterranean passage of about 900 feet through solid rock has been made; but it has not been wrought for many years, owing to the facility with which the article is obtained from mines in the west, especially from Missouri. There are inexhaustible quarries of marble and limestone, and an abundance of granite of the best description for building. Soapstone, slate, ochre, and other mineral productions, are also to be met with in various parts.

Massachusetts.

A greater number of persons are engaged in commerce in this than in any other state in the Union. It shares in the greater proportion of the bank and whale fisheries of the United States. In this branch of industry many thousands of men are employed. The shipping is more extensive than that of any other state; and in the importance of its foreign commerce Massachusetts is second only to New York. The principal articles of export are,—fish, beef, pork, lumber, ardent spirits, flax-seed, whale-oil, spermaceti, and various manufactures, as those of cotton cloth, boots and shoes, leather, cordage, wrought and cast iron, nails, woollens, straw bonnets, hats, cabinet-work, paper, oil, and muskets. There is an extensive national establishment for the manufacture of arms at Springfield.

There being no very large rivers in Massachusetts to facilitate intercourse far into the interior, a number of canals were undertaken about the beginning of the present century; but since the introduction of railroads these have sunk into insignificance, and are almost entirely disused. There was the Middlesex Canal, of about 37 miles in length, connecting Boston Harbour with the waters of the interior of New Hampshire. Around the falls in Connecticut River, called Turner's Falls, at South Hadley, there is a canal cut through solid rock, more than 40 feet deep and 300 feet long. Other falls on the Connecticut, above and below South Hadley, have been obviated by canals, dams, and other improvements, which make the river navigable for boats throughout the whole of its course in this state, and as far as Bath in New Hampshire. The Blackstone Canal extended from Providence in Rhode Island to Worcester in this state, about 45 miles S.; but it has now been rendered almost, if not quite useless, by a railroad nearly upon the same line, completed a few years since. The Farmington Canal extends from the city of New Haven in Connecticut to the S. line of Massachusetts, there connecting with the Hampshire and Hampden Canal, which extends to Northampton on the Connecticut River, a distance of about 35 miles.

The railroads of Massachusetts are the most striking feature of internal improvement which the state presents. Of these, in 1856 there were within its limits 1450 miles. The most important are,—the Western 156 miles, Boston and Maine 83 miles, Old Colony and Fall River 87 miles, Vermont and Massachusetts 77 miles, Norwich and Worcester 66 miles, Fitchburg 68 miles, Boston and Worcester 68 miles, Boston and Providence 55 miles, Boston and New York Central 75 miles, Boston and Lowell 28 miles, Worcester and Nashua 46 miles, Providence and Worcester 43 miles, Connecticut River 52 miles, Eastern 60 miles, Cape Cod 47 miles, Cheshire 54 miles, New Bedford and Taunton 21 miles, Salem and Lowell 17 miles, Nashua and Lowell 15 miles. The lengths of the roads here given include the branches. Their construction, together with the equipments for running cars upon them, cost about L.12,000,000.

The colleges in Massachusetts are,—Harvard University at Cambridge, founded in 1636; Williams at Williamstown, founded in 1793; Amherst at Amherst, founded in 1821; Holy Cross, Worcester, founded in 1843; Tuft's College, Somerville, founded in 1854. All of these are Protestant institutions, except the Holy Cross, which is Catholic. Harvard College has a library of upwards of 100,000 volumes; Amherst has about 20,000 volumes. At Andover there is a well endowed theological institution. Academies and other schools for advanced pupils are found in all the principal towns in the state. No less important are the common town schools, established by law, which requires that every town and district containing fifty families shall be provided with a school or schools equivalent in time to six months for one school in a year; one containing a hundred families, twelve months; and so on: and the several towns in the state are authorized and required to raise such sums of money as are necessary for the support of the schools, and to assess and collect the money in the same manner as other town taxes. The schools are under the supervision of a school committee, chosen annually by each town. These committces consist of from three to seven persons. In 1855 the amount raised by taxation for the support of schools was about L.237,000, and the number of schools was 4215. There is a school fund, which, in the end of the same year, amounted to about L.338,750. The interest of this fund is annually distributed among the towns. The number of incorporated academies in the state is seventy-one, for the support of which there are local funds of about L.135,000.

Slavery has not existed in Massachusetts since the Revolution. The Supreme Court of the state decided in 1783, that as, by the declaration in the Bill of Rights, "all men are born free and equal," slavery could not exist under it. This was a virtual abolition of slavery in Massachusetts, and there has never been any disposition among the inhabitants to restore it.

From the census, bearing date, June 1, 1855, the population of Massachusetts as shown at that time, was 1,133,123. The state is divided into fourteen counties, the names and population of which follow:—Barnstable, 35,877; Berkshire, 52,791; Bristol, 87,425; Dukes, 4401; Essex, 151,167; Franklin, 31,655; Hampden, 54,852; Hampshire, 35,485; Middlesex, 194,082; Nantucket, 8064; Norfolk, 94,448; Plymouth, 61,513; Suffolk, 171,818; and Worcester, 149,545. Included in the population, there are about 9000 negroes, or persons of colour. They are scattered all over the state, but reside chiefly in the cities or populous towns. There are now in the state thirteen cities. These, arranged according to the dates of their charters, are as follow, together with the populations in 1855:—Boston (county of Suffolk), 160,508; Salem (Essex), 20,933; Lowell (Middlesex), 37,553; Roxbury (Norfolk), 18,477; Cambridge (Middlesex), 20,473; Charlestown, (Middlesex), 21,472; New Bedford (Bristol), 20,389; Worcester (Worcester), 22,286; Lynn (Essex), 15,713; Newburyport (Essex), 13,357; Springfield (Hampden), 13,788; Lawrence (Essex), 16,114; Fall River (Bristol), 12,680. The towns containing 5000 inhabitants and upwards are,—Chicopee, Adams, Pittsfield, Attleborough, Taunton, Beverly, Gloucester, Haverhill, Marblehead, South Danvers, Northampton, Newton, Somerville, Waltham, Woburn, Nantucket, Abington, North Bridgewater, Plymouth, Dedham, Dorchester, Quincy, Randolph, Weymouth, Blackstone, Fitchburg, Milford, and Chelsea.

The aggregate value of the products of the state, for the year 1855, is L.61,629,310. This amount is thus divided among the different counties:—

Barnstable.....	L.644,259	Principal products from the mackerel and cod fisheries.
Berkshire...	2,657,555	Do. Manufacture of woollen goods.
Bristol.......	6,110,078	Do. Sperm and whale oil.
Dukes........	158,798	Do. Sperm candles and oil.
Essex.........	8,301,671	Do. Boots and shoes.
Franklin....	1,049,635	Do. Horses, oxen, cows, and calves.
Hampden...	2,525,093	Do. Manufacture of cotton goods.
Hampshire..	1,463,100	Do. Horses, oxen, cows, and calves.
Middlesex...	12,126,174	Do. Cotton goods.
Nantucket...	335,167	Do. Sperm candles and oil.
Norfolk	5,050,845	Do. Boots and shoes.
Plymouth ...	2,684,313	Do. Boots and shoes.
Suffolk.......	10,039,366	Do. Clothing.
Worcester...	8,483,256	Do. Cotton goods.

There were at the commencement of the present year (1857) 172 banks in the state, with L.22,148,063 capital; of these thirty-six were in Boston, and contained above one-half of the whole banking capital of the state.

The first permanent settlement made in Massachusetts, was by a small colony of English, not numbering above one hundred and two persons, men, women, and children. They came in the inclement month of December, in the year 1620, and landed in a desolate and barren place, to which they gave the name of Plymouth. Eight years after, a second settlement was effected in another part of the coast. The place of this settlement was called Salem. There were indeed other attempts at settlements between 1620 and 1628, but they either failed, or were so inconsiderable as to be overlooked in a general view, as was the case at the point afterwards called Boston, and an adjacent island. Two years after the settlement at Salem, however, a large company of emigrants arrived, and occupied the district where Boston now stands. The settlers of Plymouth had fled to this country that they might enjoy their peculiar religious sentiments without molestation. This is partially true with respect to those who settled in Salem and Boston. Massachusetts did not originally include Plymouth, which was a separate colony, had its patent, and was governed by its own laws. The Massachusetts charter was annulled by the king in 1686. In 1692 the two colonies were united in one, and governed by a viceroy until the year 1776, when the American colonies were separated from Great Britain.

The constitution of the state of Massachusetts was formed in 1780, and revised in 1820. Amendments of minor importance were made in 1831, 1833, 1837, 1840, and 1855. As a form of government it is substantially the same now as it was when originally formed. The legislative power is vested in a Senate and House of Representatives, which together are styled the "General Court of Massachusetts." The General Court meets annually at Boston on the first Wednesday of January. The Senate consists of 40 members who are chosen by districts annually. The House of Representatives consists of from 300 to 400 members who are elected annually. By the amendment of the constitution adopted in 1840, every corporate town having 1200 inhabitants is entitled to one representative; larger towns are entitled to as many additional representatives as the number 2400 is contained times in the number of its inhabitants over 1200. Smaller towns are entitled to one representative as many times in ten years as the number 160 is contained in the number of its inhabitants; and also one representative on the year in which the valuation of property is taken, being every tenth year. For the purpose of being more frequently represented, towns having less than 1200 inhabitants each may unite themselves into districts, and then be entitled to be represented in proportion to the population of the districts. As the population of the state increases, a greater number of inhabitants is required as the basis of representation in accordance with a sliding scale.

The governor or chief magistrate is elected annually by the people, and is assisted in his office by a council of eight members, also elected annually by the people, voting in districts, each district being entitled to one councillor.

The right of suffrage is granted to every male citizen twenty-one years of age (except paupers and persons under guardianship), who has resided within the commonwealth one year, and within the town or district in which he may claim a right to vote, six calendar months immediately preceding any election, and has paid a state or annuity tax assessed upon him within two years preceding such election; and also to every citizen who may be by law exempted from taxation, and who may be in all other respects qualified as above mentioned. Further amendments of the constitution are in contemplation, and have already received the sanction of the legislatures of 1856 and 1857, and require nothing more for their final adoption but the sanction of the popular vote. By one of these, the number of members of the House of Representatives is to be reduced to 240, who are to be chosen in districts, and the right of representation is to be in exact proportion to population. By another, the ability to read and write is to be added to the qualifications necessary for the right of suffrage.

The judiciary power is vested in courts established by the legislature, and in justices of the peace. The judges of the courts and the justices of the peace are appointed by the governor with the consent of the council. The former hold their offices during good behaviour; the latter for seven years. The supreme judicial court, as at present established, consists of six judges. It has original and exclusive jurisdiction in the trial of all capital offences, and in all cases of divorce and alimony; with few trifling exceptions, it has original and exclusive jurisdiction of all civil causes in which relief is sought in equity; also in all real actions, except for the foreclosure of mortgages. In the county of Suffolk it has jurisdiction concurrently with the superior court of the county of Suffolk, in all actions at law except real actions in which the amount in controversy exceeds 3000 dollars (L.625); and in the other counties concurrently with the court of common pleas, in all such actions where the amount in controversy exceeds 300 dollars (L.62, 10s.). It has appellate jurisdiction in all matters heard in the probate court. It has a general superintending power over all inferior tribunals; and all questions of law determined in any of them, where there is no right of appeal upon the facts, may be brought into this tribunal by writ of error, bill of exceptions, or otherwise, and reheard. In trials of actions at law before a jury, and in hearings of questions of fact on probate appeals in matters of equity, and in cases of divorce and alimony, the court is held by a single judge; but in capital trials, and in the hearing of all questions of law brought from the inferior tribunals, or on exceptions taken to the ruling of a single judge of its own bench in any matter tried before him, the court is held by not less than three judges, and usually by a full bench.

The superior court of the county of Suffolk consists of four judges. It has civil jurisdiction in the county Suffolk, concurrently with the supreme judicial court in all actions at law except real actions, when the amount claimed exceeds 3000 dollars. It has exclusive jurisdiction in all such actions where the amount claimed is less than 3000 dollars and more than 100 dollars (L.20, 16s. 8d.); and jurisdiction concurrently with justices of the peace when the amount claimed is less than 100 dollars and more than 20 dollars (L.4, 3s. 4d.). It has jurisdiction in all cases of crimes not capital, except breaches of the peace, trifling assaults, larcenies of small amount, and other slight offences. It has appellate jurisdiction of all cases tried before justices of the peace. The court of common pleas consists of seven judges. It has in the other counties the same jurisdiction which the superior court of the county of Suffolk has in that county; except only that in actions at law it has jurisdiction concurrently with the supreme judicial court in all actions in which the amount claimed is more than 300 dollars (L.62, 10s.). Justices of the peace have civil jurisdiction concurrently with the superior court and court of common pleas, in cases where the amount claimed is more than 20 and less than 100 dollars; and exclusive jurisdiction where the amount claimed is less than 20 dollars. They have criminal jurisdiction in cases of breaches of the peace, trifling assaults, larcenies of small amounts, and other slight offences. In all cases tried before them there is a right of appeal. In the city of Boston, and in several other cities of the commonwealth, there are established police and justice courts; with the jurisdiction of justices of the peace in other places.

There is in each county a probate court, having jurisdiction in the probate of wills, settlements of estates of deceased persons, and guardianship of minors, idiots, lunatics, and others. There is also in each county a court of insolvency, having jurisdiction in cases of insolvent debtors, and the settlement of their estates. (S. S. D.)

MASSAFRA, a walled town of Naples, in the province of Otranto, 10 miles N.W., of Tarento. The town is picturesquely situated on the slope of a hill, and the houses stand on the very brink of a rocky chasm through which a stream has worked its way and hollowed out the sides into many fantastic shapes. Massafra is supposed by some to be the ancient Messapia; but this is called in question by others. Pop. about 7000.

MASSAROONY, or MAZARUNI, a river in British Guiana, rises in Lat. 4. 30. N., Long. 60. W.; and flows in a very irregular and circuitous course, generally N.E., till it joins the Cuyuny, and falls into the estuary of the Essequibo. This river has been explored for about 400 miles from its mouth; its course is interrupted by numerous rapids, which are generally divided by blocks of granite into many separate streams. In the lower part of its course it contains numerous small islands. The scenery of its upper course is mountainous, consisting of bold perpendicular granite cliffs.

MASSENA, ANDRÉ, Prince of Essling and Marshal of France, was the son of a wine-merchant, and was born at Nice in 1758. At an early age he enlisted into the French service as a private in the Royal Italian regiment, but after having served fourteen years without rising higher than an inferior officer, he retired disheartened from military life. The French Revolution, however, reanimated his warlike ambition, and in 1792 he was appointed to the command of a battalion of the national volunteers of Var. As his valour and talents had now fair scope, his rise was rapid. In 1793 he was appointed general of brigade, and in 1795 he commanded the right wing of the army in Italy as general of division. In this capacity he acted no mean part "at the terrible bridge of the Lodi," and for his brilliant repulse of Beaulieu at Roveredo, he earned from his commander-in-chief, Napoleon, the surname of "the favourite child of victory." So marked was his conduct at the battle of Rivoli in 1797, that he afterwards received the title of *Duc de Rivoli;* and so high had he now risen in the estimation of Bonaparte, that he was despatched to France by that general to present to the Directory the ratification of the treaty of peace with Austria. In 1798 Massena was entrusted with the invasion of the States of the Church, but being accused by his soldiers of avarice, he was forced to lay down his command soon after his appointment. Receiving, however, in the following year, the command of the army in Switzerland, he defeated the Russians at Zurich, and thus saved France from the invasion of the allied armies of Russia and Austria. On the return of Napoleon from Egypt in 1800, Massena was sent to consolidate the shattered remains of the Italian army, and to check the successes of Austria. With a mere handful of troops, and with little ammunition, and less provisions, he threw himself into Genoa, and resisted the beleaguering Austrians, until he was compelled by famine to yield to an honourable capitulation. A few days after this Bonaparte routed the enemy at Marengo, and Massena was replaced in his command. But grasping cupidity was again the cause of his disgrace, and he was soon afterwards superseded by Brune. Massena, however, possessed a military genius that could not be spared in those troublous times. He was therefore created a marshal of France in 1804, and in the following year was once more appointed to the command of the army in Italy. After opening the campaign by the capture of Verona, he received several severe checks from the Austrian army under the Archduke Charles. Yet when the enemy retreated from Italy, Massena hung upon his rear, and ultimately effected a junction with the grand army of Napoleon. In 1806 Massena was commissioned at the head of a large army to accompany Joseph Bonaparte to his new kingdom of Naples. From Italy he was summoned in 1807 to command the right wing of the French army in Poland. But his military genius was chiefly conspicuous in the Austrian campaign of 1809. He saved the French army at Essling by his desperate defence of the village of Aspern, and his directing skill and animating bravery contributed in no small degree to the decisive victory of Wagram. For these services Bonaparte conferred upon him the title of Prince of Essling, and loaded him with riches and honours. As the reputation of Massena became greater, it was submitted to greater tests. Accordingly in 1810 he was chosen by Napoleon to stop the advance of Wellington in Portugal, and was commissioned "to drive the English and their sepoy general into the sea." But the wary strategy and imperturbable firmness of the British general proved resistless, and Massena was compelled to save his military fame by a masterly retreat. Ill in health, and chafing under disappointment, Massena retired to his native Nice, and was not again entrusted with a post until 1813. He was then appointed to the command of the Eighth Military Division at Toulon. In 1814 he sent in his submission to Louis XVIII., and was in return confirmed in his appointment, and created Commander of the Order of St Louis. With some reluctance he transferred his allegiance to Napoleon on his return from Elba, and he remained inactive during the Hundred Days. After the disaster at Waterloo he again submitted to the Bourbons, and was appointed commander of the national guard. Marshal Massena died in April 1817.

MASSILIA (the modern *Marseille*), a Greek town of Gallia Narbonensis, on the S. coast, was situated on a rocky peninsula E. of the mouth of the Rhone. It was founded by a colony of Phocæans, from the Ionian confederation in Asia Minor, upon a site granted to them by Nannus, king of a Ligurian tribe. The settlers were commanded by Simos and Protis, according to Justin, or by Euxenus, the father of Protis, according to Aristotle. The date of the settlement is uncertain. Encompassed on all sides by lawless barbarians, the Massaliots were often assailed both by stratagem and by open violence. Yet they not only defended themselves with success, but gradually extended their territory, and in no long time had planted along the coast several colonies, such as Antipolis (*Antibes*), Nicæa (*Nice*), Agatha (*Agde*), and Emporiæ (*Ampurias*). The sterility of their soil forced them to become a commercial people, and as their well-sheltered town formed a commodious port for vessels, they speedily acquired both wealth and influence. Accordingly, on the outbreak of the second Punic war in 218 B.C., Massilia was of sufficient importance to be received into the alliance of Rome. It was a faithful and useful ally to Cæsar during all his Gallic campaigns. Adopting, however, the cause of Pompey at the commencement of the civil war, the town was besieged by Cæsar; and after a long and stubborn resistance it was compelled to capitulate, and deliver up all its ships, military equipments, and public money. From this period Massilia, though it retained its independence, began gradually to decline. The growing importance of the Roman colony, Narbo Martius (*Narbonne*), probably affected its commercial prosperity. It however acquired a new importance as the school where the neighbouring Galli studied rhetoric and philosophy; insomuch, that in the reign of Augustus and Tiberius it came to be considered the Athens of the West, and among many other Roman youths, Agricola, the conqueror of Britain, was educated there. After the time of Cæsar the history of Massilia comprises no event of interest.

The Massaliots were noted for their simplicity, temperance, and virtue. Their government was aristocratic, and consisted of 600 dignitaries called Timuchi. A committee of fifteen chosen from these held the administration and delegated the executive power to three of their own number.

MASSILLON, JEAN BAPTISTE, one of the greatest pulpit orators of France, was the son of François Massillon, a notary of Hières in Provence. He was born on the 24th of June 1663, and entered, when very young, into the College of the Oratory in that city. Having been destined by his father for the profession of a notary, he was early withdrawn from college; but as he never ceased to return thither at his leisure hours, the superiors, remarking his dispositions, addressed solicitations to his father, in order to obtain his permission to attach the youth to themselves; and, in the year 1681, young Massillon entered the congregation, where he studied theology under Father Beaujeu, afterwards Bishop of Castres. In the year 1689 he wrote to Father Abel de Sainte-Marthe, general of the Oratory, that, as his talents and his inclination equally disqualified him for the pulpit, he conceived that some employment in teaching philosophy or theology would suit him better. Nevertheless, having been ordained priest, some panegyrics preached by him determined his superior to direct his talents to the ministry of the pulpit. After having professed the belles-lettres and theology at Pézenas, Montbrison, and Vienne, and after delivering some funeral orations, he was in 1696 called to Paris, to assume the direction of the seminary of Saint-Magloire. It was there that Massillon composed his first ecclesiastical Conferences, which are characterized by so much simplicity and vivacity. He was an ardent admirer of Bourdaloue; but he did not regard him as a model in everything, because he wished to open a new path for himself. Massillon observed that the preachers of his day were too much occupied with external manners, or vague and general moralities; and he resolved to search in the heart of man for the secret workings of the passions, in order to discover their motives, and combat the illusions of self-love by reason and sentiment, as well as by the attraction of happiness united to religion. Such was the distinctive character of his eloquence. In 1698 he went to preach during Lent at Montpellier, where he was warmly received, notwithstanding Bourdaloue had not been forgotten. Being now known, he could no longer fly from his renown, which soon recalled him to the capital. In 1699 he preached during Lent at Paris, in the church of the Oratory, and obtained a triumph which would have intoxicated a preacher who had less self-knowledge, with, perhaps, greater pretensions to humility. On a particular occasion, being congratulated by one of his brethren on the admirable manner in which he had preached; "Stop, Father," said he; "the devil has already told it me more eloquently than you." Massillon appeared in the pulpit with downcast looks, without gesture, and without parade. Nevertheless, when he warmed with his subject, his look and gesture became so expressive, that Baron, the celebrated actor, having gone to hear him, was so much struck with the correctness of his delivery, that he observed to one of his companions, "My friend, here is an orator; but as for us, we are only actors."

Being appointed preacher to the court at Versailles for the advent of 1699, the father of the Oratory appeared there without pride and without timidity, and produced such a powerful impression on Louis XIV., that he addressed to him, in presence of the whole court, the words, "Father, I have heard several great orators, and I have been satisfied with them; but as for you, whenever I hear you, I am dissatisfied with myself." The language of Massillon, though noble, was not the less simple, and adapted to the comprehension of the humblest; it was always natural and just, without labour and without affectation, and hence it had equal attractions for persons of all classes. The first time that he delivered his celebrated sermon on the small number of the elect, was at Saint-Eustache, when the whole auditory rose up, in the midst of the peroration, at once transported and dismayed. This prosopopœia, which still astonishes in the perusal, has been chosen by Voltaire in the article *Eloquence* in the *Encyclopédie*, as an example presenting "la figure la plus hardie, et l'un des plus beaux traits d'éloquence qu'on puisse lire chez les anciens et les modernes." In 1704, when Bossuet and Bourdaloue were both removed by death, Massillon preached a second Lent at court, and with such success that Louis XIV. expressed a desire to hear him every two years; but from whatever cause, he never again appeared in the pulpit of Versailles, until he pronounced the funeral oration of the king in 1715. In 1709 he likewise delivered the funeral sermon of the Prince of Conti, in the church of Saint André-des-Arc, which was much applauded when delivered, though sharply criticised after it had been printed. After more than twenty years spent in preaching, Massillon, promoted by the regent to the bishopric of Clermont, in 1717, was appointed to preach before the king during Lent. This was his last effort, but it is also his masterpiece. Massillon had nearly attained his fifty-fifth year when he composed his *Petit-Carême*, which made him be called the Racine of the pulpit. In these discourses refined views and delicate touches of humanity compensate, by elegance and grace of expression, for the bolder ornaments and deep pathos of his ordinary style. An eloquence more gentle and more insinuating, because intended to make an impression upon a young prince, thus forms the characteristic of the *Petit-Carême*. Voltaire himself, on more than one occasion, transfused several passages from one of these discourses into his own verses, and had the *Petit-Carême* always on his desk, regarding it as one of the best models of prose eloquence. In the year 1719 he was received into the French Academy. But he was far from being dazzled by these honours, and soon set out for his diocese, which he only left in 1721 to pronounce at St Denis the funeral oration of the Duchess of Orleans. Following the advice of Cardinal de la Rochefoucauld, Massillon prepared his episcopal *Conférences*, so full at once of earnestness and severity. His *Discours Synodaux* and his *Mandements* are grave instructions, conveyed in language remarkable for simple and natural elegance. The conduct of Massillon, as a pastor and bishop, corresponded to his zeal. All his actions were characterized by a wise and amiable moderation. He was eminently charitable and humane, and was always ready to raise his voice or use his purse in behalf of the poor or the oppressed. In a word, his whole life was a practical commentary on the divine precepts which he had so eloquently enforced; and he died, as he had lived, breathing sentiments of the most exalted piety, on the 18th of September 1742. The nephew of Massillon published a good edition of his uncle's works, in 14 vols. Paris, 1745–46. Of the more recent editions, we may mention those of Méquignon, 14 vols. 8vo, 1818; of Besançon, Chalandre and Son, 3 vols. large 8vo, 1847, which contains various pieces never before published. The *Eloge de Massillon* by D'Alembert was read to the French Academy in 1774, and printed in the first volume of the History of the Academy in 1779. The reader may also consult the *Principes* and the *Essai sur l'Eloquence de la Chaire* of the Abbé Maury, and the *Cours de Littérature* of Laharpe. (J. B—E.)

MASSILLON, a town in the county of Stark, state of Ohio, North America, on the left bank of the Tuscarawas River, which is here crossed by a handsome stone bridge, 112 miles N.E. of Columbus. The town is regularly and substantially built, and contains many fine stone edifices. The neighbourhood of Massillon is a rich agricultural district; and the town is, in consequence, a great emporium for the produce. The manufactures are also considerable; and iron-ware and flour are the chief products. The annual value of the exports and imports is calculated to amount to above L.1,000,000. Pop. (1853) 4000.

MASSINGER, Philip, an eminent dramatist of the age of Shakspeare, was the son of Arthur Massinger, a gentleman in the service of the Earl of Pembroke, and was born at Salisbury in 1584. It has been conjectured that he received his early training at Wilton, the Wiltshire seat of the Pembroke family. But a more likely opinion is, that he was educated in his native city, at that school which afterwards numbered Addison among its pupils. In May 1602 he was sent to Oxford, probably at the charge of the Earl of Pembroke, and was enrolled a commoner of St Alban's Hall. There, according to Anthony à Wood, he eschewed the severe studies of logic and philosophy, and pleasantly squandered his hours in reading poetry and romance. Before he had completed the round of studies necessary for a degree, he was forced abruptly to leave the university, on account, as is generally believed, of the withdrawal of his patron's supplies. Of this withdrawal different explanations have been given. Gifford solves the difficulty by imagining, from certain passages in *The Virgin Martyr*, that Massinger was a Roman Catholic, and by unwarrantably inferring from this that he changed his faith at Oxford, and thus displeased his patron. Equally unsatisfactory is the explanation of Davies, who ascribes the event to Massinger's misapplication of his time. For it is by no means probable that William, the third earl of Pembroke, a man of a generous and liberal disposition, and a well-known patron of poets, and especially of dramatists, would cast the son of an old servant of his family penniless upon the world, simply because he devoted his attention to literature. There must evidently have been a more grievous cause of offence.

From Oxford Massinger repaired to London in 1606, where he devoted his life to the cause of the drama, and became the fellow-worker and rival of such men as Shakspeare, Jonson, and Fletcher. His biography, after this period, is little else than an account of the dates at which his principal plays were written. We know, however, that he toiled on in a modest privacy till the day of his death, producing two or three plays in a year, struggling at the same time in the gripe of poverty, and living unknown and neglected even while his admirable productions were calling forth the applause of the theatres. There is still extant a letter in which he requests Henslowe, a theatrical manager, to rescue him from a pecuniary difficulty. So often, indeed, was he in extreme destitution, that in dedicating one of his plays, he says, "I had not to this time subsisted, but that I was supported by your frequent courtesies and favours,"—an acknowledgment which on some similar occasions he makes in nearly the same words. How Massinger was engaged immediately after his arrival in London is not recorded. Urged by daily necessities, and afraid of risking his valuable time on a work of his own, he was probably content to be employed in assisting dramatists of an established fame. It is certain at least, that about 1613 he had been engaged as a joint-author with Fletcher, Field, and others. At first he was compelled to labour submissively under the shadow of some great dramatist, and to content himself with little of the profits, and less of the fame derived from their joint productions. In course of time, however, when his genius had asserted its proper place, other play-writers became desirous of having his name conjoined with their own on the title-pages of their works. Accordingly, at some period before 1623, he appeared before the public as the joint-author of *The Virgin Martyr* along with Decker, of *The Fatal Dowry* along with Field, and of *The Old Law*, along with Middleton and Rowley. Meanwhile he had written several plays by himself. Of these *The Unnatural Combat* and *The Duke of Milan* alone are extant. The rest, along with a few others of Massinger's plays, were preserved for some time in manuscript by a Mr Warburton, only to be devoted at last by that gentleman's cook to the covering of pies. *The Unnatural Combat* is full of vigour and passionate eloquence; and its plot, though marred by many disgusting incidents, retains evident traces of a master's hand. With many passages full of lofty poetical sentiments, and with an action deeply engrossing in its progress, and horror-striking in its catastrophe, *The Duke of Milan* is one of the best of Massinger's tragedies. The character of Sforza is a vivid representation of that impulsive temperament which fluctuates with the rapidity of thought between the most opposite passions. In 1623 *The Bondman* was produced at the Cockpit in Drury Lane. Its chief interest arises from the variety of its *dramatis personæ*. *The Roman Actor*, which was licensed in 1626, is not generally thought to be what its author styled it, "the most perfect birth of his Minerva." More popular and more successful, both in plot and execution, was *The Great Duke of Florence*, produced in 1627. About this time Massinger wrote his most famous play, *A New Way to Pay Old Debts*. Its principal character, Sir Giles Overreach, intended for a satire against an infamous public individual of that day, is one of those rough, strongly-marked, and one-sided creations that are peculiarly fitted to carry the popular taste by storm. Accordingly, this comedy is said to have been a great favourite "at the Phœnix in Drurie Lane," and is the only one of Massinger's plays that still keeps possession of the stage. Of the rest of its characters, Marrall, the mean-spirited yet revengeful time-server, is the most amusing and most ably drawn. In 1629 was acted *The Picture*, one of the most pleasing of its author's productions. To a plot original and romantic, is added the stronger charm of a strain of feeling tender and poetical. The more earnest sentiments of the play are pleasantly relieved by the healthy, cynical humour of Ladislaus, and the spirited practical jokes of Sophia. Equally fresh and varied is *The City Madam*, licensed in 1632. It is a satirical sketch of the ridiculous airs and blind prodigality of upstart wealth. The numerous objects in the picture are artfully grouped and strongly coloured. *The Bashful Lover* was acted with great applause at the Blackfriars in 1636. Its principal charm arises from the chivalrous love and valour of Hortensio. The other extant plays of Massinger are,—*The Renegado*, *The Parliament of Love*, *The Maid of Honour*, *The Emperor of the East*, *The Guardian*, and *A Very Woman*. The continuous toil undergone in producing so many works seems to have imperceptibly undermined the health of Massinger. On the night of the 17th March 1640 he went to bed in apparent good health, in his own house on the Bankside, and was found dead next morning. His body was attended by the comedians to the churchyard of St Saviour's, and the sad story of his obscure life and lonely death was told in the register of his interment: "March 20, 1639-40, buried Philip Massinger, a stranger."

In his graphic delineation of character, in his skilful management of a plot, and in the blended grace and dignity of his blank verse, Massinger yields to none but Shakspeare. Less pathetic and less imaginative than a few of the secondary dramatists, he is also more refined and more melodious than them all. His besetting sins are a fastidious attention to the evolving of his catastrophe, and a consequent tendency to impair the consistency of his personages by adapting them to circumstances. Yet his incidents, though laboured, are ever fresh and engrossing, and his portraitures of character, though indistinct in their minuter traits, are strikingly bold and vigorous in their outlines. His comedies are deficient in humour. They are, however, of great value as accurate and interesting life-sketches.

Regarding Massinger's personal character, we can infer from the panegyrics affixed to his plays, that he was amiable, gentle, and reserved. The dedications of his several works to his patrons also throw some light on this subject. In these we see the instincts of a true and noble nature leading him in the middle path between a mere formal expression of gratitude and a slavish adulation. Nothing can be finer than the modest and manly simplicity with which he on several occasions records in one brief sentence his own destitution and the beneficence of his noble friends. The best edition of the works of Massinger is that of Gifford, published in 1805, and reprinted in 1815. An edition, freed from all objectionable passages, forms three volumes of Murray's Family Library, London, 1830.

MASSOUAH, Massowah, or Masuah, the most important seaport of Abyssinia, is situated on an island in the Red Sea, and separated from the mainland by the channel of Adowa, 250 miles N.E. of Gondar. The island is about half a mile in length by a quarter in breadth; and about one-third of it is covered with houses. Although some of the houses are built of stone, most of them are mere huts made of poles and grass. The only buildings of any importance are the mosques. The harbour is deep and secure, and can accommodate about fifty vessels; and though the entrance is narrow, access is not difficult. Owing to the dry and rocky nature of the island, water has to be collected in large tanks, which cover about one-third of the area. Massouah has a very important trade. It is not only the principal seaport in Abyssinia, but also the largest emporium on the coasts of the Red Sea. The chief articles of export are,—slaves, horns, ivory, wax, coffee, leather, hides, butter, honey, grain, gold, and spices; while the exports consist of pepper, cotton, silks, muslins, razors, sword-blades, carpets, &c. Massouah belongs to the viceroy of Egypt, and a governor, subordinate to that dignitary, resides here. Pop. of the entire island estimated at 10,000.

MASTER AND SERVANT, a relationship constituted by mutual consent. Service or labour in this country is regarded as property, of which no one can be deprived against his will, unless he be convicted of crime, when the exaction of compulsory labour may form part of the punishment. Where a man voluntarily disposes of his labour, the law will enforce fulfilment of the contract, just as it enforces all other lawful contracts. Parties unqualified to give consent,—as, for example, pupils; that is, males under fourteen, and females under twelve years of age; or intoxicated, or insane persons,—cannot enter into such a contract; neither will the law regard the most formal contract, if it appear that it was extorted by force or fear, or was obtained by fraud. The existence of the contract may be proved by writing, or, within certain limits, by witnesses; and it may sometimes be inferred from circumstances. In Scotland, if the agreement is meant to last more than a year, writing is not only required, but it must be what is called probative writing, otherwise either of the contracting parties may repent of, and withdraw from the agreement; but if any intelligible writing, however informal, be followed by the mutual actings of parties under it, the law will regard it as obligatory. Earnest-money is not necessary, unless required by the established and uniform usage of any particular locality. When given, it is justly regarded as evidence of a concluded agreement, which the sending back of the earnest-money cannot undo. When the contract is once concluded, the parties must discharge the obligations which they have undertaken, and that personally, and not by substitution. The duties to be performed, the recompense for these duties, and the duration of the contract, are matters of arrangement. Sometimes local customs supply ambiguities in a contract, but they never prevail against express stipulations. Dishonesty or open immorality, wilful disobedience or habitual negligence or disrespect, justifies the dismissal of a servant without wages, at whatever period of the contract such an offence occurs, because the wages are not legally earned until the covenanted term of payment arrives. Excessive labour cannot be demanded from servants; nor are they bound to work at anything which is unlawful, or substantially different from, or of a decidedly lower kind than that for which they were hired. They are not bound to work on Sunday unless they be domestic or farm servants, and then it is only at such necessary work as that which from its nature requires to be performed every day. Masters are not liable in the consequences of injuries which servants may sustain while acting in obedience to reasonable orders, from which, with due care, no injury could have been anticipated. In such cases masters are not liable even for the expense of medicines or medical aid which the servant may require; though, whenever these are voluntarily provided by the master, he is not entitled to charge them against the servant. If a servant be injured through his master's unreasonable conduct or culpable neglect, the master is liable in damages to the servant, or to his heirs, if the injury terminate in his death. Complaints against the conduct of a servant must not be reserved as a set-off against payment of wages at the expiry of the contract, but must be made when they occur. A plea, for example, of incapacity or negligence against a servant is made too late when the termination of the contract has arrived and the wages have become payable; but faults complained of and pardoned till their repetition becomes intolerable, may be proved in justification of a master who at length is compelled to dismiss the servant. No servant is bound under any circumstances to submit to maltreatment at the hand of his master, nor even to such threats as create a reasonable apprehension of danger. Servants must, when required, accompany their master wherever he goes within the kingdom, provided he does not thereby do them any real injury, and agrees to bring them back in time to seek for another situation at the close of the contract; but not if they were hired with reference to a particular place or to special duties, such as to serve or work in a particular factory. Masters are under no legal obligation to give a character to any servant, and where a good one cannot truthfully be given, it is safer to give none; though, when a servant refers to his master for his character, he must take his risk of the answer, provided it be not false and malicious. If a master knowingly give a good character to an undeserving servant, he is liable to the succeeding master, by the law both of Scotland and England, in damages, and in England, by the 32d Geo. III., cap. 56, in a fine of L.20, or imprisonment with hard labour for not less than one, or more than three months. In a case in England, where a person gave a good character of a servant in the full knowledge that he was unworthy of it, and a succeeding master was thereby induced to take him into his service, and was soon thereafter robbed by him, for which the servant was tried and executed, Lord Mansfield held that the pursuer was entitled to recover the loss from the person who knowingly and falsely gave the good character. Even where a good character was honestly given, if it be afterwards discovered to have been undeserved, the master who gave it must notify the discovery to the person to whom he gave it. If a servant obtain a situation by false pretences, affirming that he served where he did not, or that he did not serve where he really did, or shall alter or erase a written character, he may be summarily dismissed, and in England is liable in a fine of L.20. We shall notice more particularly—

1. *Apprentices.*—They are distinguished from other servants in this respect, that they engage to serve their master in his particular trade or calling chiefly in order that they may learn it. Minors having no curators may enter into indentures; but if they have curators, their concurrence is necessary. Even then, the indentures may be set aside if they involve manifest and serious injury to the minor. Pupils, being legally incapable of consenting, cannot bind themselves. It is not unusual, however, for parents to bind themselves for their pupil children. The master, by himself, or a qualified overseer, must fairly instruct the apprentice in all the branches of his business, so far as the apprentice is capable and willing to be instructed, and not put him to any other employment, beyond that of teaching his fellow-apprentices the calling to which he is bound, as in doing so he improves himself. If a master die or retire from business during the currency of the indenture, the apprentice has no further claim than that another equally well qualified master be found in the same locality, to whom the indenture may be transferred; but no transference can be effected without the apprentice's consent. The bankruptcy of the master puts an end to the indentures, leaving the apprentice to rank on the master's estate for a proportion of the apprentice-fee, or damages. Changes in the constitution of a company, however, do not free the apprentice, provided one or more of the original partners remain to carry on the business. The articles of indenture generally specify a penalty against either party failing to perform his part of the contract, but the court will modify the penalty to the actual damage. As a master stands somewhat in the relation of a parent to an apprentice, he is not entitled to dismiss him for every trifling fault, but he may do so if, after warnings, the apprentice prove incorrigible or incapable, or if he commit a single act of dishonesty or gross immorality; and the master is not bound to take him back on promises of amendment, as his bad example may be pernicious to the master's other apprentices. Notwithstanding such an offer, the master may even sue for the penalty. Apprentices put to trade by a parish, or any others on whose binding no larger sum of apprentice-fee was paid than L.25, may, by the 20th Geo. II., cap. 19,—and apprentices on whose binding no sum whatever was paid, may, by 5th Vict., cap. 7,—be punished to the extent of a month's imprisonment, by two justices, for any ill behaviour, and to the extent of three months for desertion. But these statutes are understood to be confined to the particular classes of apprentices mentioned in them and in 17th Geo. III., cap. 56. Under these statutes masters who beat their apprentices improperly may also be punished. By the common law the enlistment of an apprentice does not destroy the indentures; but the statute 48th Geo. III., cap. 15, only enables the master to reclaim him, provided he is then under twenty-one years of age; that the apprenticeship was for four years; that the indentures were produced to, and indorsed by, a magistrate before the enlistment, and within three months after their date; and that the master claim the apprentice, and make oath before a magistrate, within one month after the enlistment.

2. *Workmen and Labourers.*—Unless a special agreement can be proved, the period for which they are engaged, their hours of labour, and even the amount of their wages, are regulated by the usages of their particular trade. If there be no general usage as to wages, a court of law will either fix what is reasonable, or remit the matter to a jury. The legal presumption is, that service must be remunerated. Ordinary workmen and labourers are generally presumed to have been hired by the day or week; and farm servants, gardeners, overseers, grieves, &c., by the year. In an action for wages by the foreman of a silk factory, Justice Park said (1833)—"The presumption is, that the plaintiff was hired for a year, and nothing being proved contrary to that presumption, and he having violated his duty before the year expired, so as to prevent the defendant from having his services for the whole year, he cannot recover wages,"—not even rateably for the time he has served, as the full term must be completed before wages are due. If servants work in their

own dwellings, they may retain the goods of their master, on which they have expended their labour, in security of their wages, but not if they work in their master's premises. On the bankruptcy of their master, farm servants and reapers have a preferable claim on his crop for their current wages; and their wages are not attachable for their debts so far as necessary for their subsistence. Provision is made by the statutes 22d Geo. II., cap. 27; 17th Geo. III., cap. 56, and 58th Geo. III., cap. 51, for the summary conviction and punishment of workmen in certain trades who purloin, embezzle, pawn, or sell their master's materials or tools; and neglect to return unused materials within eight days after demand, is held to be embezzlement. Amongst the trades referred to in these statutes are hatters and workers in woollen, linen, fustian, cotton, iron, leather, fur, hemp, flax, mohair, and silk, and workers in any of these materials mixed, and also dyers and hot-pressers. The knowingly purchasing or taking embezzled materials by any person from such workmen is severely punishable; and where such materials are found in the possession of the receiver, the burden is laid on him of proving that they came into his possession in a lawful manner. Under these statutes one justice of the peace may issue a warrant for the apprehension of accused parties, but two are required for conviction. An appeal lies to the next general or quarter sessions, on the party entering into recognisances, with security, to abide the result.

The statute 4th Geo. IV., cap. 34, provides that if any servant in husbandry, or artificer, calico printer, handicraftsman, miner, collier, kealman, pitman, glassman, potter, labourer, or other person under contract by a signed writing, shall not enter to, or having entered, though not under a written contract, shall absent himself, or shall be guilty of any other misconduct or misdemeanour in the execution of the contract, it shall be lawful to any justice of the peace of the place where such servant contracted, or is found, upon complaint on oath, to issue a warrant for apprehending him, and to examine into the complaint, and, if proved, to commit him to hard labour not exceeding three months, or to punish him by abating the whole or part of his wages. The provisions of this statute are, by the 10th Geo. IV., cap. 52, extended to all persons engaged, whether as servants, apprentices, or otherwise, in the several manufactures, trades, and occupations above named, alluded to in the statute of 17th Geo III., cap. 56. Under these statutes a workman of any of the classes above referred to may be punished if he produce an insufficient quantity of work, or be disobedient, or refuse to work, or desert. If he commit a higher offence than these—as, if he steal his master's goods or break into his premises—the offender may be prosecuted, as the law directs, in a higher criminal court. It is decided that these statutes do not apply to cases where the parties do not stand towards each other in the precise relation of master and servant; as, for example, if a master employ a workman to execute a specific piece of work for a gross sum, or if the employer by the contract have no title to require the workman to work at any particular time or place, but only that the work shall be done within the covenanted period. In such cases it would be competent to the workman to accept simultaneously of any other employment from other individuals, so that he could not strictly be termed the servant of any particular master. Accordingly, in England it was found that a contract to build a wall for a given sum, within a specified time, did not bring the workman within the statutes; Justice Park remarking, that to do so, there must be a contract for service exclusively to one employer. The words "or other persons" are added to the specification of servants given in the statutes, and it is often difficult to determine to whom they refer. They do not refer to menial or domestic servants, but to persons hired for out-door or country labour, and generally to all who, by the rules of any particular trade, must give a definite warning before they are entitled to quit their master's service. Complaints under these statutes do not require the concurrence of any public prosecutor. They usually begin with the oath of one of the complainers. If the warrant following on the complaint requires to be executed in a county different from the one in which it was granted, the concurrence of a justice of peace of such other county is necessary. A workman deserting from England and going to Scotland, or deserting from Scotland and going to England, may be apprehended on a warrant granted in the county from which he deserted, provided it be indorsed by a justice of the county to which he has absconded. When he is apprehended, the subsequent proceedings must be in strict conformity with the statute, otherwise they will be quashed. When followed by conviction, the workman is subjected to the punishment authorized by the statute; but Lord Ellenborough observed, that "it would be clearly against the policy of the law, if the servant, by his own act of delinquency, should have the power of dissolving the contract," merely because he has undergone punishment inflicted for the breach of it; and, therefore, after being punished, he is bound to return to his service and complete his engagement to his master.

By the statute 1st and 2d Will. IV., cap. 37, it is provided that the wages of certain workmen (of whom a very comprehensive description is given) shall be paid in the current coin of the realm, or notes of the Bank of England, or other bankers entitled to issue notes, or in drafts or orders payable to the bearer on demand, within fifteen miles of the place; otherwise the contracts cannot be enforced by the master. This provision applies to servants connected with the getting of coal, lime, stone, slate, clay, bricks, or salt; or engaged in the manufacture of iron or steel, or of articles of hardware, or plated articles, cutlery, or goods made of brass or other metal, or japanned goods, and almost all kinds of cloth, silks, and lace; leather, glass, and earthenware. The object of the statute is to prevent the frauds which were too often practised on workmen, by masters keeping provision stores, and selling articles of bad quality at a high price, in payment of wages. There is nothing to hinder the wages of such servants as do not fall under the classes specified in the statute, from being paid in any way that may be arranged; but any attempt to control the mode in which any workman may spend his wages is illegal. If, in face of the last-mentioned statute, even although the consent of the workman be obtained, the master retain the price of goods out of the wages, and the workman, or his wife, widow, or child in minority, should within three months after become chargeable to the parish, such parish is entitled to compel the master to pay over again the wages so retained. There are various exceptions to this rule, intended for the advantage of the workman, such as the cost of medicines or medical attendance, tools for mining, hay or corn to be consumed by any beast of burden employed in his trade by the workman, the rent of his house, or of victuals dressed and consumed under his own roof, or money advanced to a friendly society or savings-bank to relieve him in sickness, or to educate his children. Where advances of that kind are made by the master, they may, notwithstanding the statute, be deducted from the wages, provided they are made under a written agreement to that effect. Masters contravening the statutory regulations may be punished by a fine not exceeding L.10, nor under L.5 for a first offence; not exceeding L.20, nor under L.10, for a second offence; and not exceeding L.100, at the discretion of the court, for a third offence;—ten days intervening between each offence, otherwise each separate offence is held as a first. Every succeeding offence beyond the third is treated as a third offence; and the right to prosecute is not held to be abandoned until the lapse of two years. The different classes of workmen last above alluded to may, on complaint to a justice of the peace, be discharged of their contract with their masters on proof of ill treatment, refusal of stipulated provisions or wages, cruelty or other ill usage.

Attempts have been made to prevent or abridge litigation between masters and workmen. By the 5th Geo. IV., cap. 96, provision is made for settling some particular disputes by arbitration; and improvements on that statute have been made by 7th Will. IV., 1st Vict., cap. 67, and 8th and 9th Vict., cap. 77. It would altogether exceed the bounds allotted to this article to attempt to specify the kinds of dispute which may be so disposed of, or to explain the proceedings which must be adopted. It is safer to refer to the statutes themselves, only observing, generally, that on either master or workman going before a justice of the peace, the justice has power to settle the dispute in a summary manner, provided both parties agree in writing to abide by his determination. If they decline, then the justice may propose four or six persons, one-half being masters, agents, or foremen, and the other half being workmen, out of whom the master may select one, and the workman another, to act as arbiters, whose determination is final. If they differ in opinion, the justice may then act as umpire. If both parties agree to a different mode of adjustment, the law gives effect to their agreement. We are not aware that these provisions have been acted on so frequently as they should; on the contrary, we fear that combination is, unhappily, too often resorted to rather than arbitration.

3. *Of Combinations.*—This leads us to notice the improvement, in favour of workmen, which was effected by the statute 6th Geo. IV., cap. 129. Previous to that statute the most peaceable combination on their part to raise their wages was an indictable offence. For this there was no sound reason whatever, provided all acts of violence were avoided. That statute, therefore, made it lawful, alike to masters and workmen, to combine for the purpose of regulating wages and all the other conditions of labour. Since then, combinations have been somewhat frequent in Great Britain. On the part of workmen, their principal objects have been to fix a minimum rate of wages, to diminish the hours of labour, to decrease the quantity of work, to prevent masters taking more than a specific number of apprentices according to the number of journeymen employed by them, and to support each other during their refusal to work, in the hope of forcing their masters to comply with their terms. Of course, the object of the combinations on the part of masters is to counteract those of the workmen, and to secure terms more favourable to themselves. While these objects are sought to be attained by discussion and appeals to reason, with merely refusal in the absence of contracts to work, the law will not now interfere; and in the long run the disputes are generally equitably adjusted, though more frequently to the disappointment and loss of the workmen, who are often defeated by means of the capital of their employers, and the facilities with which other workmen can be procured from a distance. The loss and misery which workmen and their families have endured during these struggles, though the masters have not come out of them uninjured, would form an instructive chapter. So long, however, as parties not under contract conduct themselves peaceably, the law leaves them to combine for the regulation of their contracts, and to assist each other with pecuniary aid as they best can; but the instant that violence or intimidation is resorted to, an offence is committed which is justly punishable with great severity. To threaten a master or any one with violence is punishable at common law. To molest or intimidate a workman, to compel him to join an association, or to prevent him from hiring himself on such terms as he may please, is punishable by the statute with imprisonment for a period not exceeding three months, with or without hard labour. Of course there are many ways in which a workman may be intimidated without violence being committed, or threats uttered; and therefore the law will interfere wherever such is plainly the object of acts which in themselves may be harmless. The assemblage, for example, of numbers of persons acting in combination, whose appearance and gestures may reasonably alarm men willing to work, is in certain circumstances punishable, even though no direct act of outrage be committed. The question is, What is the purpose and object of the parties? Do they intend to create fear, and thereby force a man of ordinary resolution to abstain from working? If it be plain to a jury or to a magistrate that the object of the assemblage is to overawe, the offence is held to be committed; and such assemblages may be summarily dispersed by a magistrate. Where, however, the magistrate is not satisfied of the existence of the guilty intention, or believes that the parties have assembled only for the purpose of discussing their own grievances, he will, of course, decline to interfere; though he will not readily believe that they would choose the vicinity of factories, or the roads to and from workmen's houses, as suitable places for such discussions. The procedure under the statute is summary. It enacts,—"That if any person shall, by violence to the person or property, or by threats or intimidation, or by molesting or in any way obstructing" workmen, force, or endeavour to force them to quit their work, or to refrain from hiring themselves, or to cause them to join the combination or contribute to any common fund, or force any master to make any alteration in his mode of carrying on his business, or to limit the number of his servants,—parties so offending shall, on complaint within six months, be brought before any two justices of the peace, who, after finding the charge proved by the oath of one or more credible witnesses, shall adjudge the offenders to be imprisoned, with or without hard labour, for any period not exceeding three months. But it is to be observed, that this statute does not by any means take away the cognisance which the common law takes of such offences, or hinder them from being stated as aggravations of an ordinary assault in a higher court; so that if the grounds of complaint be considered too serious for the adjudication of justices, proceedings may be adopted before the ordinary criminal courts, in which sentences have been pronounced varying from six to eighteen months' imprisonment, and from four to fourteen years' transportation, according to the nature of the violence proved.

4. *Servants in Factories.*—The following statutes have been passed for the relief of women and children employed in factories, viz.,—42d Geo. III., cap. 73; 3d and 4th Will. IV., cap. 103; and 7th Vict., cap. 15. A great variety of objects are sought to be attained by these statutes; among others, the prevention of oppression by excessive work; the limiting of the hours of juvenile labour, and hindering night work; the education of children, securing to them suitable dormitories, ventilation, meals, clothing, holidays, and precautions against accidents. We cannot enter into details. The statutes apply to all cotton, woollen, and other factories wherein steam or water, or any mechanical power, is used to work the machinery; and wherein three or more apprentices, or twenty or more other persons, are at any time employed. No child under eight years of age can be employed in such factories, nor until thirteen years of age can any child be kept at work in them for more than six hours and thirty minutes, or, in some cases, seven hours, a day. In certain events such children may be employed ten hours on each of three alternate days, so that their labour throughout the week is not increased. The certificate of a surgeon as to the fit-

ness of such children for the work is required. Between the age of thirteen and eighteen years, young people may be employed twelve hours a day, but not more than sixty-nine hours in any one week, nor during the night between half-past eight o'clock in the evening and half-past five in the morning; and no person under eighteen years of age can be employed after half-past four on the Saturday afternoon. Females above eighteen years of age cannot be employed longer or otherwise than persons between the ages of thirteen and eighteen. Holidays are secured to the extent of eight half-days annually. The statutes do not apply to persons employed in repairing machinery or packing goods; but they prohibit the employment of children to clean machinery while it is in motion. To enforce these regulations government inspectors are appointed; and masters, under penalties, must keep a register of a great variety of particulars, open to the examination of the inspectors. They must also fence their machinery to the satisfaction of the inspectors, unless, on a reference to arbiters, it be ascertained either that it is sufficiently, or that it cannot be better fenced.

5. *Servants in Printworks.*—Regulations are enacted in reference to them by the 8th and 9th Vict., cap. 29, very similar to those applicable to the class last above referred to.

6. *Miners and Colliers.*—By the 15th Geo. III., cap. 28, and 39th Geo. III., cap. 56, these labourers, who previously were literally in a state of bondage, were placed on the same footing with other servants. The 5th and 6th Vict., cap. 99, was passed chiefly to prevent masters from employing boys under ten years of age, and females, in mines; and to render it illegal to enter into indentures with boys for more than eight years, or to intrust any person, except males above fifteen years of age, with the charge of steam-engines by means of which persons are passed up or down a shaft, pit, or inclined plane. It is also unlawful to pay the wages of miners in a public-house; otherwise payment may again be enforced. In all these instances penalties are incurred for any violation of the regulations; and government inspectors are appointed to secure that the regulations are enforced.

7. *Chimney-Sweepers.*—The 3d and 4th Vict., cap. 85, enacts that no person shall be bound apprentice to a chimney-sweeper under sixteen years of age, or be compelled to go up or down a chimney under twenty-one, either for cleaning it or extinguishing a fire, under penalties.

8. *Seamen and Sea Apprentices.*—The statutory provisions on behalf of these classes of servants are too numerous to permit us, within our limits, to give any specification of them. We must therefore refer such of our readers as require information about them to "An Act to amend and consolidate the Acts relating to Merchant Shipping," 17th and 18th Vict., cap. 104, amended by 18th and 19th Vict., cap. 91. We have also to refer to 17th and 18th Vict., cap. 120, for an enumeration of all the prior acts and parts of acts relating to merchant shipping which are repealed or continued. We may state generally that all merchant vessels (not pleasure yachts) of 80 and under 200 tons burdens, must have one apprentice; 200 and under 400 tons, two apprentices; 400 and under 500 tons, three apprentices; 500 and under 700 tons, four apprentices; and 700 tons and upwards, five apprentices at least, who must be above twelve and under seventeen years of age, bound for four years at least, subjects of Her Majesty. They may be employed in any ship during the currency of the indentures of which their master is owner or master. The statutes define with great minuteness the nature and form of their agreements, and enact summary modes for compelling them to join and to remain with the ship, and for the regulation of their conduct at sea. They also make anxious provision for their good treatment by their masters both at home and abroad, and for enforcing all their just claims against their masters.

9. *Domestic Servants.*—They differ from all other servants chiefly in these respects,—that they are not entitled to absent themselves from their master's family, except in cases of extreme necessity, without leave; they must avoid all nice distinctions about their work; give ready obedience, "not answering again." They have no fixed hours of labour, but must work if required, in so far as is consistent with their health and strength. Any act of indecency or dishonesty justifies immediate dismissal, as does a repetition of an instance of intoxication. Bad health relieves them from their duties while it lasts, and when it is not imputable to gross misconduct, their wages are not diminished, unless it become very protracted. The precise length of time is not invariably fixed. In ordinary cases in Scotland, where the hiring is generally for six months, six weeks must be submitted to. In one case, where the engagement was for a year, a fifth part of that time, under special circumstances, was allowed. The domestic servant is not bound to make up the time lost by sickness. The law of England does not authorize the master to turn away the servant on account of sickness; but if he go away without leave, the contract is dissolved. If the sickness be the result of debauchery, or if the servant concealed bad health existing at the time of hiring, or if he have contracted debt and be imprisoned for payment, his master may put an end to the engagement. The endurance of the engagement depends on special agreement, or is regulated by custom. It is usually, in England, terminable on a month's notice; and in Scotland it lasts for six months, terminable on a warning of forty days; and after such warning is given, the servant is entitled at suitable times to go in quest of another situation. Till the warning be given by either party wishing to bring the engagement to a close, it is held to be tacitly renewed. During its currency or renewal the domestic servant cannot maintain residence in the master's house against his will, but must remove on being required. If, however, the removal be enforced on insufficient grounds, the servant is entitled to wages and board-wages, and even damages, if accompanied by cruelty, such as turning a friendless female out of doors at an unseasonable hour. The marriage of a servant of either sex, or the enlistment of a man-servant, is not a misdemeanour; so that if they can arrange to complete their term of service, the master must perform his part of it; but by the Mutiny Act the enlistment interrupts the service, and entitles a justice of the peace to award to the servant a proportion of his wages. In England it rather appears that a woman marrying during the period of her service cannot be withdrawn from it by her husband until its termination. In Scotland the husband may withdraw her, but he is liable to her master in compensation for the loss of her services. If a domestic servant die before the termination of the engagement, the executors can only claim wages for the period actually served. If the master die, the claim of the servant is exactly what it would have been in the case of unwarrantable dismissal, with this qualification, that the master's executors liable in such a claim are entitled to have the service till its legal termination. Sometimes the amount of wages has not been fixed by the parties, as, for example, where a destitute young person is taken into a family, and works, with little advantage at first to the family, till at length the services become useful, nothing having been said about wages; and then the question has arisen, whether in such circumstances wages are really due. Both in England and Scotland it has been decided, that where service is given, wages must be paid. In such cases the amount is fixed judicially, on a consideration of the whole circumstances. Loss by accidental breakage by a servant cannot legally be deducted from the wages, unless it evidently arose from gross carelessness. Servants have no preferable claim for wages on the bankruptcy of

their master, as farm servants have; but if his death occur during the currency of the engagement, they are generally ranked on his estate after the undertaker and landlord.

10. *The higher order of Servants than those above alluded to, such as Governesses, Tutors, Clerks, Managers, of Establishments, and Editors.*—It can scarcely be said that any practice or usage with reference to them has been so uniform and long-continued as to constitute a rule. Some of those hirings, such as of managers and editors, are so important that they are probably always made the subject of special bargain. Where such contracts are during pleasure, they may be terminated without any cause being assigned. Whenever it appears from the circumstances, that the parties had undoubtedly some considerable period in view, a year at least will be presumed. In a Scotch case, where a course of tuition by a tutor was evidently contemplated, and in an English case, where a warehouseman was to receive wages at the rate of so much monthly, with a progressive rise till they reached a given sum per annum, engagements for a year were presumed. Clerks would rather appear in Scotland to be hired during pleasure, and in England they are understood to be hired for a year. In a case before the English courts relative to clerks it was remarked,—"We must decide this case according to the general rule, and hold the contract between the parties to be a hiring for a year."

In conclusion, we may remark (1), That a practice existed in Scotland by which masters obtained summary warrants to apprehend servants who deserted during the currency of their engagement, and imprison them until they found security to return to their service; and that practice was justified by a judgment of the Court of Session pronounced so recently as 1824. That judgment, however, was pronounced after a very imperfect discussion, and its soundness has been much questioned. The origin of the practice must be sought for at a time when servants were not regarded as being equally the objects of the protection of law with their masters, and when they were probably under the arbitrary regulation of the magistrates, than which nothing can be more objectionable. There is nothing in the contract between master and servant unlike other civil contracts. On either side a failure to fulfil the contract gives rise to a claim of reparation, which ought to be recovered like other civil claims; and the very fact that it has been thought right, by special statutes, to enforce the obedience of some classes of servants, seems to imply that, in the absence of such statutes, a contract of service with others should only be enforced by the ordinary forms of law.

2. None of these statutes can be stretched beyond their clear enactments, nor extended to classes to which they do not expressly apply, as they can only be justified by the peculiar necessities of particular trades.

3. The history of combinations proves that, whether on the part of masters or workmen, they are useless and mischievous. On the part of skilled workmen their objects, in addition to those above referred to, are sometimes to require that masters shall hire no workmen unless they be members of their union, and that in the order in which their names are engrossed in the union-books, nor at less than their fixed rate of wages; otherwise all combined workmen strike work. Sometimes it happens that these demands are so excessive, that masters are forced to combine in turn, and stop their works, until the unionists reduce their demands, or can be replaced by servants from a distance, thereby involving thousands of workmen and their families in destitution. The attempt of the workmen to sustain themselves, during the *strikes*, out of a common fund has generally failed—the money gathered being insufficient. The tendency of combination is injurious to the workmen, because it destroys all inducements to industry among them; seeing that if masters are only to hire workmen in the order of their enrolment, and all at fixed rates, the inferior and idle are placed on a level with the industrious and skilful. Such a system, which will always be popular with inefficient workmen, operates just as would be the case if all physicians and lawyers were employed by rotation and at the same fees, which would no doubt be relished by the men of inferior talents in both professions, but would paralyze the exertions of the most eminent. This is quite obvious; and yet workmen who disapprove of unions are often compelled to join them, because, unless they do so, the other workmen would not remain in the service of their master. In the end great injury is inflicted on both parties, though generally most heavily on the workmen. In 1834 the west of Scotland was convulsed by a strike among calico printers which lasted nine months. Intimidation, which was resorted to, was counteracted by the military, and was followed by merited punishment. In one establishment business was suspended, and two thousand workmen, with their families, were thrown into destitution. At length that establishment, after an adjustment with its creditors, resumed business with new hands procured from a distance at reasonable wages, while the unionists were scattered in starvation over the country. This was not a rare example. While, therefore, skilled workmen are permitted to try every lawful means to better their condition, their success depends mainly on their rendering it, by good conduct, the interest of their masters to employ them. The competition which must ever exist among masters will always induce them to give the highest wages they can afford, to secure the best workmen; and any attempts to force wages above that point must force the attention of masters to improvements in machinery, and the training of unskilled labourers to supersede the refractory. The regulation of labour and wages depends on principles which can only be affected by combinations for a very limited period; while nothing workmen can do, will permanently check the pressure of their own numbers on the means of employment. Wherever labour is abundant it will be cheap; and when workmen resort to intimidation they engage in a most unequal conflict with the law; while skill and attention, according as they are in demand, will generally find their place in the market. (M. L.)

MASTIC, or MASTICH, the μαστίχη of the ancient Greeks, is a concrete resinous exudation from the trunk and branches of the *Pistacia lentiscus* (Nat. Ord. *Anacardiaceæ*), a bush about 12 feet high, growing on the coasts and islands of the Mediterranean, and particularly the island of Chios, where it is very abundant, and is extensively cultivated for its resin. Mastic is produced either by spontaneous exudation or by transverse incisions made in the bark in the month of August, when the resin exudes in tears, and either hardens upon the tree or falls to the ground. In the former case it is of a superior quality, and is called picked mastic, consisting of roundish, elongated, or flattened tears, varying in size between a pepper-corn and a hazel-nut, of a pale yellow colour, and translucent, brittle, and glassy in fracture, and possessing a slight but agreeable balsamic odour and taste. This kind of mastic is sometimes adulterated with sandarach. The coarser kind, called mastic in sorts, is of a greyish-brown or black colour, and is rendered impure by the presence of fragments of wood, bark, and sand, collected by the resin in falling to the ground.

Mastic, besides containing traces of volatile oil, produces by dissolution in boiling rectified spirit a white ductile substance, which some have regarded as a peculiar principle under the name of Masticin. Mastic is much used by the Turkish ladies for consolidating the gums, cleaning the teeth, and sweetening the breath. When chewed it becomes ductile, grey, and opaque. It is also employed occasionally for stuffing decayed teeth. It is chiefly used in this country for compounding varnishes, and is imported from the Grecian Archipelago packed in chests.

MASULIPATAM, a considerable town and seaport of Hindustan, in the Northern Circars, and the principal place of the district of the same name. It is defended by a fort, which is of a rectangular figure, 800 yards in length by 600 in breadth, and situated in the midst of a salt morass, close to an inlet or canal, which communicates with the sea and the Krishna, so that the adjoining grounds may be inundated at pleasure; and this constitutes its principal defence. The port is not capable of receiving vessels beyond the burden of 300 tons, the shore being flat and the water shallow; ships are consequently compelled to anchor at some distance from land. The town is situated on a piece of ground rising above the fort, a mile and a half to the N.W., and communicates with it by a straight causeway 2000 yards in length. Many of the houses are large, and well built of brick and lime mortar, with upper storeys and tiled roofs, and most of the dwellings of the poor are commodious and clean, in consequence of the neatness indispensably required for the manufacture of cotton chintzes, for which the place has been long famous. The population of the town has been returned at 27,884; Lat. 16. 10., Long. 81. 13. The district, of which this town is the chief place, has an area of 5000 square miles, with a population amounting to 544,672. It forms one of the Circars which were obtained by the French in 1753, and remained in their possession till 1759, when Clive transferred them to the East India Company, to whom they were formally ceded in 1765 by the Emperor of Delhi.

MATAMORAS, or MATAMOROS, a town and port of Mexico, department of Tamaulipas, situated on the right bank of the Rio Grande, about 40 miles from its mouth. The town is well built, and is the seat of a considerable trade. The principal articles of export are specie, horses, wool, and hides; and the imports consist of manufactured goods from Great Britain and the United States. The town has but recently grown to its present importance, from a small village. Pop. about 10,000.

MATAN, a small island of the Philippines, near the E. coast of Zebu; Lat. 10. 16. N., Long. 123. 48. E. It is about 10 miles in circumference, and is only noted as the place where the navigator Magalhaens was killed in a skirmish with the natives in 1521.

MATANZAS, a seaport of Cuba, on the N. coast of the island, at the head of a deep bay, 57 miles E. of Havaña; Lat. 23. 2. N., Long. 81. 38. W. The town is well built, about a third of the houses being stone, but without much pretension to architectural beauty. The principal buildings are two churches, an hospital, barracks, theatre, and public library. The harbour is protected by a natural breakwater, consisting of a ledge of rock 4 feet below the surface, through which entrance is afforded by two channels, one to the N. and the other to the S.; but the former only is passable for large ships. The harbour has also been much reduced in size and depth by the mud carried down by two rivers, one of which flows on each side of the town. The number of vessels that entered the harbour in 1851 was 499; that cleared, 578. In the same year the exports amounted in value to L.393,641, and the exports to L.1,119,453; while the duties collected on imports were L.118,372, and on exports L.63,561. The surrounding country is one of the richest districts of Cuba; and the bay is large and convenient for ships, being sheltered from every wind but the N.E. Previous to 1809, owing to the restrictions put upon its trade, Matanzas was a place of small importance; but in that year these were removed, and the result has been an increase, not only in the commerce of the town, but in the raising of sugar, coffee, and other articles in the neighbourhood. The principal articles of export are sugar, molasses, and coffee. Pop. (1854) 26,000.

MATARO, a seaport of Spain, on the Mediterranean, in the province and 21 miles N.E. of Barcelona; N. Lat. 41. 32. 5., and E. Long. 2. 28. 24. The town is beautifully situated, partly on the slopes of the Cordillera which separates the coast from the Vallés, and partly on the plain beneath. Hills, covered to the summits with vines, shelter it in the form of an amphitheatre from the cold northern winds. The streets of the new town, the part of the city next the sea, are handsome and regular. The most notable buildings are the church of Santa Maria, dating from 1675, which contains some good pictures; the hospital; and the theatre. There are schools of navigation and of the fine arts; but the chief educational institution is the college of PP. Escolapios, founded in 1737, and in 1829 incorporated with the university of Cervera. Close to the walls flows the small River Cirera. The principal agricultural product is wine, which is exported by Barcelona. There is a considerable fishery, the results of which are disposed of inland, in Manresa and other places. The railway connecting this town with Barcelona, which was opened in October 1848 (the first in Spain) has given a great impulse to the industry of Mataro. It is entirely a manufacturing town. There are ten cotton factories, of which seven are worked by steam; also of cotton and woollen cloth, silk, velvet, and stockings. The manufacture of canvas and of tarpaulin is extensively carried on, and several hundred women are employed in making lace. There are numerous potteries and various chemical works; leather, glue, glass, bricks, and some other articles are also made. The trade is carried on chiefly through Barcelona, Mataro having no artificial harbour, and the attempts at various times to construct one having been frustrated. The modern name of the town, Mataro (μάραθρον?), appears, according to some, to correspond with the ancient Latin name *Civitas Fœnicularia.* Mataro enjoyed many privileges from the Spanish monarchs in reward for its generous assistance in their naval expeditions. The most melancholy page of its history is the cruel sack it underwent from the French on the 17th of June 1808. The celebrated Capmany, author of the *Teatro Historico-critico de la Elocuencia Castellana*, and other excellent works, was a native of this town. Pop. (1845) 13,010.

MATCHES. Previous to the invention of the common lucifer match, the contrivances for procuring light, while frequently ingenious, were generally attended by some serious inconvenience. The plan adopted by savage nations is the laborious one of igniting by friction two pieces of dry wood. A readier method, but still a clumsy contrivance, was the flint and steel and tinder-box, in common use among ourselves till about thirty years ago. Attempts were made to supersede the tinder-box by such expensive and complicated contrivances as the *pyrophorus*, the *pneumatic tinder-box* or *light syringe*, the *hydrogen-lamp* of Dobereiner, &c.; yet the present simple and convenient lucifer is rather an improvement on the sulphur match than a modification of any of those more complex arrangements. One of the first forms of improved match was based on the fact that chlorate of potash, mixed with suitable ingredients, is decomposed by sulphuric acid, with the production of fire; the sulphur match was accordingly tipped with a paste composed of 30 parts chlorate of potash, 25 parts sulphur, 2 parts colophony, 1½ vermilion, and 2 of gum in solution; and the match thus prepared was dipped into a bottle containing asbestos moistened with sulphuric acid, and rapidly withdrawn, when an explosive flame was generated which set fire to the wood. These matches, although inconvenient, soon became common, and were sold at 1s. per box under the name of *Eupyrion.*

The next form of the chemical match obtained the name of *Prometheans.* In this contrivance the paste consisted of equal parts chlorate of potash and sugar, mixed with a solution of gum. The sulphuric acid was ingeniously contained in a small glass bead, which, with a small quantity of the paste, was rolled up in gummed paper. On pinching the extremity of the roll with a pair of pliers, the bead was crushed, and the acid coming into contact with the chlorate, produced a burst of flame.

The next improvement was the *friction-match*, which appeared about the year 1832. In this contrivance the sulphur match was tipped with a composition consisting of 1 part chlorate of potash and 2 parts sulphuret of antimony, mixed with gum water. This match was ignited by drawing it briskly through the folds of a piece of sand-paper held between the finger and thumb.

The chief improvement in the match was the introduction of phosphorus into the composition of the paste, with which many ingredients were tried, such as magnesia, lime, sulphur, white-wax, cork-powder, &c., while chlorate of potash continued to be used; and as this material produced on ignition a noisy crackling sound, resembling Congreve rockets, the name of *congreves* was applied to the matches. When this explosive noise was got rid of, matches were called *noiseless lucifers*, and subsequently *lucifers*, a word which has found a permanent place in our language.

The manufacture of lucifer matches is at the present time of vast extent and importance; a single manufacturer exporting from London alone not less than 8000 cwt. of matches every year. The first operation at one of these factories is the sawing up of the timber into blocks, each 30 inches in length, 4½ in width, and 3 inches in thickness, by means of a circular saw, cutting across the fibres, so that each plank furnishes about 30 blocks. From these blocks *splints* for the matches are cut by means of a machine, patented by Reuben Partridge in 1842. Each block is placed endwise in a frame furnished with a crank bearing a horizontal arm, at the end of which is a block containing from thirty to forty lancet-points, separated by pieces of brass of the thickness of the intended match. The motion of the crank brings the lancet-points under the end of the block, and the points cut or score the wood to the required depth for forty splints. As the lancet-points are withdrawn by the revolution of the crank, a knife is made to swing round horizontally, and mow off a layer from the end of the block thus scored, containing forty splints each, two matches in length. The knife is then withdrawn, the lancet-points again advance, and the process is repeated as before. The splints fall into a room below, where they are made up into bundles of 1000 each, and afterwards dried in rooms heated to the temperature of 300°. When the bundles are taken out, both ends are dipped into melted sulphur, a kind of twist being given to each bundle to prevent the splints from being glued together by the sulphur. The bundles are now divided, each into two halves, by means of a circular saw, and are ready for tipping with the phosphorus paste, after which they are packed into boxes. The composition of this paste varies with different manufacturers; but the principle of its action is the same in all common matches, viz., an emulsion of phosphorus is made with glue or gum, and this being applied to the end of the sulphured matches, they are exposed in a warm room until a sufficient quantity of the phosphorus has been driven off by slow combustion, so as to leave a sheet of glue or gum, which protects the remaining phosphorus from the oxidizing influence of the air. When the end of the match is drawn briskly across sand-paper, a portion of this gelatinous envelope is removed, while the heat occasioned by the friction ignites the phosphorus, and sets fire to the sulphur. The composition contains, among other ingredients, sand for promoting the friction, and colouring matter—such as red ochre, smalt, or artificial ultramarine. Matches of this kind ignite with great facility without any noise, and are therefore dangerous; while the large proportion of phosphorus which they contain renders them highly poisonous. Increased hardness, and consequently greater safety, is given by the use of chlorate of potash; but this makes a noisy match, and produces a white bursting flame. In some cases nitre is used instead of chlorate of potash, the oxygen of both the salts assisting the combustion of the phosphorus. Some of the matches made in Germany for use in climates less moist than that of England, are tipped with a composition of gum, nitrate of lead, or peroxide of lead and phosphorus. In well-compounded preparations the proportion of phosphorus may be very small, not more than from 5 to 10 per cent. Some use the following compound:—Phosphorus, 1 part; nitre, 10 parts; fine glue, 6 parts; smalt, 2 parts.

The great objection to all ordinary pastes is the use of common phosphorus, which fills the air of the factory with fumes of phosphoric acid, whereby the health of the workpeople is greatly affected, and in many cases necrosis of the lower jaw produced. The only complete preventive consists in the employment of the *red* or *amorphous phosphorus*, discovered by Schrötter a few years ago, and which is not volatile. It is said that Herr Lundström, of Jönköping has successfully employed the red phosphorus lately in the following manner:—The matches are tipped as usual with sulphur, stearine, spermaceti, or wax, and then with a composition consisting of 6 parts chlorate of potash, from 2 to 3 of sulphuret of antimony, and 1 part of glue; while, instead of the usual sand-paper on the match-box, the sides of the box are covered with a friction paste consisting of 10 parts of red phosphorus, 8 parts oxide of manganese or sulphuret of antimony, and from 3 to 6 parts of glue. This ingenious arrangement is said to be perfectly successful, and if so, it deserves the name of *safety-match*, which has been proposed for it, since this kind of match cannot take fire by accidental friction, while such matches are not poisonous, as is the case with common lucifers.

The *vesta*, or taper-match, consists of a wick of untwisted cotton, covered with wax, and tipped with an inflammable paste containing a large proportion of chlorate of potash. In preparing these matches, from 100 to 200 lengths of wick, kept separate by means of combs, are made to pass through a bath of melted wax, and then through holes in a metal plate, which draws them to the proper size and shape. They are next cut into lengths for the vestas by a machine-moved knife, and being arranged on frames, are tipped with the composition. *Fusees* for lighting cigars are prepared from strips of cardboard, steeped in a solution of nitre, and cut nearly through into the required number of lights.

The manufacture of lucifers is spread over a considerable part of the world, and forms a vast and increasing trade. It is said that in this country at least 40,000,000 matches are made *per diem*, while large quantities are imported from Germany and other parts. In this country, where the extent of the manufacture is much less than in Germany, upwards of 8 tons of phosphorus, and 26 tons of chlorate of potash, are consumed every year for tipping matches. The cheap rate at which lucifer matches are manufactured is remarkable. It is said a German manufacturer will sell a case of 50 boxes, with 100 matches in each box, for 4d. (C. T.)

MATCHIN, a town of European Turkey, in Bulgaria, situated on the right bank of the Danube, 32 miles N.E. of Hirsova. It is defended by two forts; and was the scene of a victory gained by the Turks over the Russians on 24th December 1853.

MATELICA, a town of Italy, in the States of the Church, situated on the River San Angelo, a tributary of the Esina, 23 miles W.S.W. of Macerata. It is an old town, surrounded by walls, and contains several churches and convents. The inhabitants are chiefly occupied in the cultivation of the neighbouring country, and in the manufacture of coarse woollen stuffs. Pop. 7270.

MATERA, a town of Naples, capital of the province of Basilicata, is situated in a deep valley on the right bank of the Gravina, a tributary of the Bradano, 128 miles E. by S. of Naples, and 44 E. from Potenza. The town, which is defended by walls, is generally well built; and contains a cathedral and archiepiscopal palace, which have porticos consisting of granite Corinthian columns, supposed to be the remains of an ancient temple. Not far from the walls stands an old tower known by the name of Torre Metella; and there are also in the town six convents and a college. The neighbouring country is rich in pastures; and the valley is surrounded by hills, which contain many curious caverns. Pop. 12,000.

MATERIA MEDICA. The signification given to this term by different authors has varied very much indeed, some employing it to denote the whole range, and others only a particular department, of that branch of medical science which relates to the means employed for the prevention or in the treatment of diseases. Prophylactic or preventive, and remedial or curative means, may be referred to three principal divisions: 1st, The performance of manual operations; 2d, The regulation of what have been termed the non-naturals, as of diet, exercise, temperature, clothing, &c.; and, 3d, The employment of medicinal substances. Manual operations, as far as their mode of performance is concerned, fall under the domain of surgery; the regulation of the non-naturals is the object of dietetics and hygiene. As to the third division (medicinal substances), they may be considered either in reference to the sources from which they are derived, or to the modes in which they are prepared for medical use; or they may be considered, along with the other two classes of means, in reference to the immediate purposes for which they are employed in the treatment of diseases, and the *indications* which they are intended to fulfil. Now, the term materia medica has by some been understood as embracing the consideration of remedies in all these respects. But by others, and, as we conceive, more correctly, it has been limited to signify the natural and commercial history of medicinal substances. Those processes by which medicinal substances are fitted for use constitute the department of pharmacy, whilst the purposes for which remedies are employed form the objects of consideration in therapeutics. Some have employed the word pharmacology as a general term, to include the whole of the knowledge that has been obtained relative to remedies.

MATERIALISM is the name given to that speculative theory which resolves all existence into a modification of matter. (See METAPHYSICS.)

MATHEMATICS (μάθησις or μάθημα) properly signifies the discipline of the mind acquired in studying a science, rather than its subject matter; and is a term descriptive of any species of knowledge which tends to improve the mental faculties. It is employed, however, in a restricted sense, to denote the science whose object is the discovery of the abstract relations of number and magnitude, and their application, by means of observed laws, to the explanation of natural phenomena, and the improvement of the useful arts.

Although in every department of mathematics results are obtained by strictly logical deduction from a few first principles explicitly assumed, yet the science may be regarded as consisting of two distinct branches, according to the nature of the evidence on which the truth of its first principles is admitted. In the one, which constitutes *pure mathematics*, the first principles require no special inductive process to convince us of their truth, and scarcely, indeed, demand the evidence of our senses. Whether they are notions inherent in the mind, or deductions from our constant and earliest experience, they are universally allowed to be self-evident, in the sense that we cannot conceive them to have been otherwise than they are. Thus pure mathematics is founded upon definitions of necessary truth, and is pre-eminently the most certain of all the sciences.

Mixed mathematics denotes the application of *pure* mathematics to natural objects; and presupposes some knowledge of their properties derived from the senses, or of general laws obtained by induction from a sufficient number of observations. The logical, or strictly mathematical processes of deduction in the pure and mixed mathematics are identical; the difference between the two sciences being, that in the one, the first principles are self-evident, while in the other, laws and facts, which are not necessarily self-evident, but derived from observation, are admitted, along with the axioms and definitions of pure mathematics, as fundamental principles of the science. Again, in mixed mathematics we are often presented with conclusions derived from hypotheses regarding the constitution of nature. If we ask whether these are correct conclusions from the assumed hypotheses, our investigations must be conducted on principles purely mathematical: but if we inquire whether the conclusions have a real existence in nature, we must appeal to observation; and our reasoning becomes inductive. It is from this mixture of mathematical deduction with experimental processes that the mixed sciences derive their name, and not from any difference between their mathematics and those of pure science.

Thus the evidence for the conclusions of mixed mathematical science is inferior to that obtained in pure mathematics, only in so far as the utmost confidence in the truth of laws arising from even the highest degree of probability attained by inductive reasoning, must always fall short of the conviction which follows from the perception of necessary truth. If, however, we estimate the rank of a science by the perfection of its methods,—the power it confers of pursuing the most lengthened and complex processes of reasoning with perfect certainty of the correctness of the results—its consequently perpetually extending and cumulative character—the almost hopeless difficulty of the problems it has solved—the remoteness of the conclusions to which it has conducted the inquirer into natural laws—the number and importance of the truths with which it has enriched mankind—or, in short, the almost incredible degree in which it has aided and amplified the reasoning faculties,—we must accord both to pure and mixed mathematics the first place among the various departments of human knowledge.

The different branches of mathematical science may be classified as follows:—

I. Pure mathematics consists of the following branches:—

1. *Arithmetic*, which may be subdivided into *pure arithmetic*, or the ordinary science of numbers, and of numerical calculations conducted by means of the common arithmetical notation; and *algebra*, or the methods of calculation by means of general symbols, so far as the processes are restricted to actual numerical operations. (See ARITHMETIC.)

2. *Geometry*, which investigates the properties of figures in the manner of Euclid's *Elements*, without the aid of algebraical processes. (See GEOMETRY, and CONIC SECTIONS.)

3. *Algebra*, or the calculus of operations, differing from arithmetical algebra in the more extended definition of its operations, and their more universal applications. (See ALGEBRA.)

4. The application of algebra to geometry, including coordinate geometry. (See ANALYTICAL GEOMETRY.)

5. The differential and integral calculus, which include the general theory of limits, or those methods of operation in which the limits of ratios are employed in calculation, and denoted by specific algebraical symbols. (See FLUXIONS.)

II. Mixed mathematics includes the application of pure mathematics to mechanics, astronomy, optics, heat, electricity, &c. (See ASTRONOMY, &c.) The theory of probabilities is usually included under this head, although it has perhaps equal claims to rank under pure mathematics.

(For the history of mathematical science the reader is referred to the articles ALGEBRA and GEOMETRY, and to the *Preliminary Dissertations.*) (W. S—N.)

MATHER, COTTON, D.D., a learned American divine, the son of Increase Mather, was born at Boston in February 1663. He received his elementary education under his father's care, and at the age of twelve he entered Harvard College with a considerable knowledge of the classics. There he studied with successful ardour, and at the same time subjected himself to a rigid system of fastings, vigils, self-examinations, and other pious exercises. An impediment in his speech induced him at one time to forego his intention of entering the church, and to commence the study of medicine. This infirmity, however, was soon afterwards overcome; and accordingly, after graduating, he began to preach in 1680. In the same year he was appointed assistant to his father in the North Church of Boston. Cotton Mather now became one of the most zealous of ministers. He discharged his professional duties most faithfully, published numerous sermons and books on practical religion, and assiduously amassed materials for intended treatises. At the same time he set himself to acquire several modern languages, and among others the Iroquois Indian. Nor did he refrain from interfering in civil affairs. A sharer in the superstitions of his age, he was a confident believer in witchcraft; and imagining that there were in the town of Boston some devotees of the evil one, he laboured with his usual honest zeal to detect them. A book of his, entitled *Memorable Providences relating to Witchcraft and Possessions, with Discoveries and Appendix*, 8vo, Boston, 1689, excited a great ferment both in England and America, and was the chief cause of that series of executions for Satanic intercourse known as the "Salem Tragedy." The tide of opinion, however, was now setting in that was destined to sweep all such superstitions away, and Cotton Mather in vain attempted to stem it by his work entitled *The Wonders of the Invisible World*, 8vo, Boston, 1693. So far had he now fallen in the public estimation, that though generally regarded as pre-eminent among his countrymen for learning and genius, he was twice passed over in the election of a president to Harvard College. Yet he continued with unabated earnestness to toil for the general welfare of his fellow-men; and in 1721 he was the first to introduce into America the practice of inoculation. He died in February 1728. Cotton Mather was the first American who was elected a fellow of the Royal Society of London. Of his numerous works his *Magnalia Christi Americana*, London, 1702, is the greatest; and his *Directions to a Candidate for the Ministry*, Boston, 1726, is the best known.

MATHER, *Increase*, D.D., the father of the preceding, was born at Dorchester, Massachusetts, in June 1639. He was enrolled at the age of twelve a student of Harvard College, where he graduated in 1656, and immediately proceeded to Dublin to complete his studies at Trinity College. Soon after his return to America in 1661 he was chosen minister of the North Church, Boston. The native energy and unflagging zeal of Increase Mather had now obtained full scope. He discharged his ministerial duties with fidelity, spent the greater part of the day in his study, published numerous sermons and other works, and was the acknowledged leader in the political discussions of the community. In 1685 he was appointed president of Harvard College; and in 1688 he was despatched to England as agent for the province, to procure redress of grievances. On his return his services were rewarded with the thanks of the House of Representatives. In 1701 he resigned his presidentship, as he thought that its duties were incompatible with those of his pastorate. He died at Boston in August 1723. The best known works of Increase Mather are,—*History of the Wars with the Indians in New England*, London 1676; and *Remarkable Providences*, reprinted as a volume of Russell Smith's Library of Old Authors, 8vo, 1856.

MATHEWS, CHARLES, an eminent comedian, was the son of a bookseller in the Strand, and was born in London on the 28th June 1776. After receiving his education at the Merchant Tailors' school, he was apprenticed to his father's business. But his early-developed love for mimicry had grown into a passion for the stage; and after playing several times as an amateur, he eventually, in 1794, engaged himself as a professional comedian at the Theatre Royal, Dublin. In the course of a year, however, the injustice of a cruel manager, and the pinchings of extreme poverty, had cooled his enthusiasm so much that he set out for England, bent upon spending the rest of his life in his father's shop. At Swansea the stage-fever relapsed, and there Mathews played for nearly three years with great popularity. Meanwhile he had married in 1797 the daughter of Dr Strong, a physician at Exeter. He removed in 1798 to the theatre at York, and by his careful study and ready talents soon became a great favourite with the play-goers of that city. But the gratification resulting from his public success was neutralized by domestic misfortune. Feeble health, pecuniary embarrassments, and the death of his wife, simultaneously overwhelmed him; and not until he had received, in 1802, a flattering invitation to become a member of the Haymarket Theatre, London, did he resume his wonted gaiety. After marrying his second wife, Miss Anne Jackson, a member of the York company, Mathews repaired to London in 1803. His success continued to increase during two seasons at the Haymarket, and afterwards at Drury Lane. On the destruction of the latter theatre by fire in 1809, he removed with the rest of the company to the Lyceum, and there he acquired additional fame by his personation of Maw-worm in *The Hypocrite.* In 1811 he set out on a provincial tour; and on his return to London in 1812 he resumed his place at the Haymarket. A severe fall from his tilbury in 1814, lamed him for the rest of his life. In 1818 the genius of Mathews, hitherto cramped by the shallow characters he had been employed to personate, gained full scope in his entertainment entitled "Mathews at Home." By a series of comic songs, personations, ludicrous adventures, and imitations of well-known actors, he filled the English Opera-House to overflowing for forty successive nights. He had thus, by one rapid stroke, gained the greatest histrionic honours, and was now considered unrivalled in the versatility of his comic powers. During the four following seasons he continued his entertainments in the same theatre with unabated applause. In 1822 he set out on a professional visit to the United States; and on his return to London in 1824, he mimicked the peculiarities of that country with inimitable effect in his "Trip to America." He continued his entertainments every season in the English Opera-House until he became, in 1828, joint-proprietor with Mr Yates of the Adelphi Theatre. In compliance with the urgent request of the American theatres, Mathews revisited America in 1834, and performed his famous "Trip," to crowded audiences, in several of the largest cities. His sinking health, however, compelled him to accelerate his return, and he died at Plymouth on the 28th June 1835.

Possessing in the highest degree a plastic countenance, a flexible voice, and a power of rapid and keen discernment, Charles Mathews stood alone in the art of mimicry. His imitation of the voice, of the physical peculiarities, of the very sentiments and mind of his subject, approached as nearly as possible to complete identification. Almost as wonderful was his dramatic power of inventing new characters. Those in his entertainments "At Home" were all designed by himself; and each of them had the finish and individuality of a true transcript from nature. The gentlemanly bearing, upright conduct, and social worth of Charles Mathews, combined with his genius to introduce him into the most select society; and he numbered among his personal friends such men as Coleridge and Charles Lamb. His son, the eminent comedian of the present day, has inherited, along with his father's name, no small portion of his talents.

MATINA, a river of Central America, in Costa Rica, formed by the union of the Chirripo and Barbilla, flows eastward, and discharges itself into the Atlantic. The Matina flows smoothly over a bed unbroken by rocks, and is navigable during the whole of its course; as also are its tributary streams for some distance above their junction. The river is subject to annual inundations, which take place generally in December and January, though sometimes at earlier or later seasons, and which leave a deposit of thick and rich mud, to which the neighbouring country owes much of its fertility and the luxuriance of its vegetation. Ships can pass into this river from the port of Moin by means of a canal called the Baya.

MATLOCK, a village of England, county of Derby, on the Derwent, 17 miles N. by W. of Derby, and 144 N.W. of London. It stands in a beautiful position on the slope of a hill to the E. of the river, which is here crossed by a fine stone bridge. The church, an edifice in the English style, surmounted by a spire 129 feet high, is picturesquely situated on the summit of a perpendicular rock overlooking the Derwent. There are four other churches belonging to different denominations, and numerous commodious and handsome hotels and other establishments for the use of visitors. Matlock is much frequented by invalids and tourists for the sake of its medicinal springs and the beauty of the scenery. The springs were first brought into notice in 1698, and have since been much resorted to, being considered beneficial in nervous debility and other diseases. There are several curious caverns in the vicinity, from which, and from mines, stalactites and spars are obtained, which are manufactured by the inhabitants into various articles, and largely purchased by visitors. There is here also a museum containing many mineralogical specimens found in the neighbourhood. The inhabitants are chiefly employed in lead mines and quarries in the neighbourhood. Matlock Dale, which has a length of about 2 miles, is full of the most romantic scenery, and surrounded by steep and rugged hills. Pop. of the parish (1851) 4010.

MATSYS, or Messis, Quintin, an eminent painter, styled from his original vocation "The Blacksmith of Antwerp" was born in that city in 1460. At the age of twenty, according to the ordinary account, he became passionately attached to the daughter of a painter; and on being informed that her father would bestow her hand upon none but an artist, he resolved to acquire that qualification, and accordingly abandoned his trade. His first painting, it is said, was a portrait of his mistress, which raised him at once to the rank of a successful suitor and an eminent artist. He died at Antwerp in 1529. The paintings of Matsys, though rather hard and dry, are finished in their style and vigorous in their colouring. Some of his heads were thought by Sir Joshua Reynolds to be equal to those of Raphael. His masterpiece is the picture of the "Two Misers," now seen at Windsor.

MATTEI, Stanislao, a pupil of the celebrated Padre Martini, was born at Bologna on 10th February 1750. His love of music was early awakened by hearing the daily service in the church of the Cordeliers; and Padre Martini having remarked his close attendance, took an interest in the boy, and induced him to enter his own convent (that of St Francis) as a novice. There Mattei was taught music by Padre Martini, took the vows, and was ordained. He remained constantly with his master till the death of the latter, who left his books and manuscripts in the hands of his pupil, with the hope that Mattei would complete the fourth volume of the *Storia della Musica*. But Mattei probably felt his incompetency, for he never published any part of that volume. The writer of this article was introduced to Mattei in Feb. 1819, and had a good deal of conversation with the old man, who spoke with great affection of his master, a portrait of whom he kept in his bedroom. Speaking of his *quondam* pupil, Rossini, he said,—"I never could get him to *study* attentively, and therefore he often writes incorrectly; but he is full of talent, and his head works like a Vesuvius." Some notice of the library of Padre Martini has been taken in this work, under the article Burney. Mattei succeeded Padre Martini as chapel-master of St Francis' church, and produced a number of masses, motets, &c., most of which remain in manuscript at Bologna. He afterwards became chapel-master of St Petronio, and held that office till his death on the 17th May 1825. In 1804 he was appointed professor of musical composition in the Liceo of Bologna, and taught many pupils, among whom were Rossini, Morlacchi, Donizetti, &c. He was president of the Philharmonic Society of Bologna in 1791-94; and in 1808 became a member of the musical section of the Italian Institute of Arts and Sciences. On 24th January 1824 he was named one of the associates of the French Academy of the Fine Arts. His work on accompaniment and counterpoint is held in no esteem except for the musical examples, which are all well written. (G. F. G.)

MATTHEW, St, the Evangelist, was, according to Mark ii. 14, the son of Alphæus; and if it is correct, as is generally supposed, that Jacobus, or James, the son of Alphæus, was a son of Mary, the wife of Cleophas, who was a sister of the mother of Jesus, Matthew was one of the relatives of the Saviour. Matthew was at all events a man of humble birth, and held the office of a *portitor*, or inferior collector of customs, at Capernaum, on the Sea of Galilee, where he was either connected with the port of Capernaum, or collected the customs on the high road to Damascus, which went through what is now called Khan Minyeh, or the ancient Capernaum. In Mark ii. 14, and Luke v. 27, he is called Levi, and hence we conclude that he had two names. This circumstance is not mentioned in the list of the apostles (Matt. x. and Luke vi.); but the omission does not prove the contrary, as we may infer from the fact that Lebbæus is also called Judas in Luke vi. 16, in which verse the name Lebbæus is omitted. We are informed in Matt. ix. 9, how Matthew was called to be an apostle; yet we must suppose that he was previously acquainted with Jesus, since we read (Luke vi. 13), that when Jesus, before delivering the Sermon on the Mount, selected twelve disciples, Matthew was among their number. After this Matthew returned to his usual occupation; from which Jesus, on leaving Capernaum, called him away. After this event he is mentioned only in Acts i. 13. Clemens Alexandrinus (*Pædagog.* ii. 1) states that Matthew abstained from animal food, a circumstance which has led some writers to conclude that he belonged to the sect of the Essenes. But while it is true that the Essenes practised abstinence in a high degree, it is not true that they rejected animal food altogether. And even admitting the account in Clemens Alexandrinus to be correct, it proves only a certain ascetic strictness in the disciple, of which there occur not unfrequent vestiges in the habits of other Jews. According to another account, which is as old as the first century, and which occurs in Clemens Alexandrinus (*Strom.* vi. 15), Matthew, after the death of Jesus, remained about fifteen years in Jerusalem. This agrees with the statement in Eusebius (*Hist. Eccles.* iii. 24), that Matthew preached to his own nation before he went to foreign coun tries. Rufinus (*Hist. Eccles.* x. 9) and Socrates (*Hist. Eccles.* i. 19) state that he afterwards went into Ethiopia; and other authors mention other countries which he visited. Heracleon and Clemens Alexandrinus agree in the opinion that Matthew was one of those apostles who did not suffer martyrdom.

MATTHEW, *St, The Gospel of,* has been more strongly attacked with respect to its genuineness than any of the other three, both by *external* and *internal* arguments.

The most ancient testimony concerning Matthew's Gospel is that of Papias, who, according to Eusebius (*Hist. Eccles.* iii. 39), wrote as follows:—"Matthew wrote the sayings in the Hebrew tongue, but everybody interpreted them according to his ability." Doubts of different kinds have been raised whether this testimony could refer to our Greek Gospel of St Matthew. These doubts were particularly brought forward by Schleiermacher in the *Studien und Kritiken*, 1832, Heft 4; whose opinion was adopted by Schneckenburger, Lachmann, and many others. According to these critics, the apostle wrote only a collection of the remarkable sayings of Jesus; which collection was put into an historical form by a Greek translator. Dr Lücke has shown, however, that the testimony of Papias may be considered as referring to our Gospel of St Matthew. Those who deny the genuineness of this Gospel allege that in none of the Fathers before Jerome do we find any statement from which we could infer that they had seen the Hebrew Gospel of St Matthew; and that consequently we may consider as a mere conjecture the opinion of the Fathers, that our Gospel is a Greek translation of a Hebrew original. Jerome, in his *Catal. de Viris Illustr.* (cap. iii.), reports that the Hebrew Gospel of St Matthew was preserved in the library at Cæsarea, where he took a copy of it; and in his commentary on Matt. xii. 13, he says, that he translated this Hebrew Gospel into Greek. Accordingly, Jerome's statement respecting the *Evangelium secundum Hebræos* may be taken as a confirmation of the account of Papias, that Matthew wrote his Gospel in Hebrew. If this be the fact, the question must arise whether our Greek Matthew is a correct translation of the Hebrew. The words of Papias seem to imply that in his days there was no Greek translation in existence; a circumstance which has induced many critics to question his account, and to suppose that the original text was Greek. Such is the opinion of Erasmus, Œcolampadius, Calvin, Beza, Lardner, Guerike, Harless, and others. It is by no means improbable, however, that after several inaccurate and imperfect translations of the Aramæan original came into circulation, Matthew himself was prompted by this circumstance to publish a Greek translation, or to have his Gospel translated under his own supervision. It is very likely that this Greek translation did not soon come into general circulation, so that Papias may have remained ignorant of its existence. On summing up what we have stated, it appears that the external testimonies clearly prove the genuineness of the Gospel of St Matthew. The authenticity, indeed, of this Gospel is as well supported as that of any work of classical antiquity. Not only was it early in use among Christians, but the apostolical fathers, at the end of the first century, ascribed to it a canonical authority. (See Polycarp, *Epist.* c. ii. 7; Ignatius, *Ad Smyrn.* c. vi.; *Ad Rom.* c. vi.; Clemens Romanus, *Epist.* i. c. xlvi.; Barnabas, *Epist.* c. iv.)

With respect to the *internal* arguments brought against the authenticity of this Gospel, it has been alleged that the representations of Matthew have not that vivid clearness which characterizes the narration of an eye-witness, and which we find, for instance, in the Gospel of John, and even in Mark and Luke; that he omits some facts which every apostle certainly knew. For instance, he mentions only the last journey of Christ to the passover at Jerusalem; and seems to be acquainted only with Galilee as the sphere of Christ's activity. It is further objected, that he relates unchronologically, and transposes events to times in which they did not happen; for instance, the event mentioned in Luke iv. 14–30 must have happened at the commencement of Christ's public career, but Matthew relates it as late as ch. xiii. 53, sq.; that he embodies in one discourse several sayings of Christ which, according to Luke, were pronounced at different times. He falls, it is asserted, into positive errors; for he seems not to know that the real dwelling-place of the parents of Jesus was at Nazareth, and that their abode at Bethlehem was only temporary; and disagrees with Mark in his account of the withered fig-tree, and in the time assigned for the purification of the temple. These circumstances have led Strauss and others to consider the Gospel of St Matthew as an unapostolical composition, originating, perhaps, at the conclusion of the first century; while some consider it a reproduction of the Aramæan Matthew, augmented by some additions; and others call it an historical commentary of a later period, made to illustrate the collection of the sayings of Christ which Matthew had furnished. (Comp. Sieffert, *Ueber die Aechtheit und den Ursprung des ersten Evangelii*, 1832; Schneckenburger, *Ueber den Urspung des ersten Evangelii*, 1834; Schott, *Ueber die Authenticität des Ev. Matth.* 1837.)

To these objections it may be replied, that the gift of narrating luminously is a personal qualification of which even an apostle might be destitute, and which is rarely found among the lower orders of people; that an *argumentum à silentio* must not be urged against the evangelists. The raising of Lazarus is narrated only by John; and the raising of the youth at Nain only by Luke; the appearance to five hundred brethren after the resurrection, which, according to the testimony of Paul (1 Cor. xv. 6), was a fact generally known, is not recorded by any of the evangelists. In the next place, there is no reason to suppose that the evangelists intended to write a chronological biography. On the contrary, we learn from Luke i. 4 and John xx. 31, that their object was of a more practical and apologetical tendency; and it is now generally admitted that, with the exception of John, the evangelists have grouped their communications more according to the subjects than according to chronological succession (com. Kern's *Abhandlung über den Ursprung des Evangelii Matthæi*, p. 51, sq.; Köster, *Ueber die Composition des Ev. Matth.* in Pelt's *Mitarbeiten*, Heft i.; Kuhn, *Leben Jesu*, t. i., *Beilage*.)

Again, if the evangelist arranges his statements according to subjects, and not chronologically, we must not be surprised that he connects similar sayings of Christ, inserting them in the longer discourses after analogous topics had been mentioned; for these discourses are not compiled by the evangelist, but always form the fundamental framework to which sometimes analogous subjects are attached. It depends, moreover, entirely upon the mode of interpretation, whether such positive errors as are alleged to exist are really chargeable on the evangelist. The difference, for instance, between the narrative of the birth of Christ, as severally recorded by Matthew and Luke, may easily be solved without questioning the correctness of either, if we suppose that each of them narrates what he knows from his individual sources of information. If these arguments should still appear unsatisfactory, they may be supported by adding the positive internal proofs which exist in favour of the apostolical origin of this Gospel. 1. The nature of the book agrees entirely with the statements of the Fathers of the church, from whom we learn that it was written for Jewish readers. None of the other evangelists quotes the Old Testament so often as Matthew, who, moreover, does not explain the Jewish rites and expressions, which are explained by Mark and John. 2. If there is a want of precision in the narration of facts, there is, on the other hand, a peculiar accuracy and richness in the reports given of the discourses of Jesus; so that we may easily conceive why Papias, *a parte potiori*, styled the Gospel of Matthew *λόγια τοῦ κυρίου, the sayings of the Lord.* Some of the most beautiful and most important sayings of our Lord, the historical credibility of which no sceptic can attack, have been preserved by Matthew alone (Matt. xi. 28-30; xvi. 16-19; xxviii. 20; comp. also xi. 2-21; xii. 3-6, 25-29; xvii. 12, 25, 26; xxvi. 13); and above all, the Sermon on the Mount, of which negative criticism grants that Luke's account is defective as compared with Matthew's, and that Luke gives as isolated sentences what in Matthew appears in beautiful connection. In short, the Sermon on the Mount, according to Matthew, forms the most beautiful and the best arranged whole of all the evangelical discourses. It may also be proved that in many particulars the reports of several discourses in Matthew are more exact than in the other evangelists; as may be seen by comparing Matt. xxiii. with the various parallel passages in Luke. Under these circumstances, it is surprising that the genuineness of this Gospel has not yet met with more distinguished advocates. The most important work in defence of the genuineness of Matthew is that of Kern, *Ueber den Ursprung des Evangelii Matthæi*, Tübingen, 1834. Next in value are Olshausen's *Drei Programme*, 1835; and the two *Lucubrationes* of Harless, 1840 and 1843. Even De Wette, in the fourth edition of his *Introduction*, p. 170, has ascribed only a qualified value to the doubts on this head. With regard to the *date* of this Gospel, Clemens Alexandrinus and Origen state that it was written before the others. Irenæus (*Adv. Hær.* iii. 1) agrees with them, but places its origin at the time when Peter and Paul were at Rome. Even De Wette grants (*Einleitung*, sect. 97) that it was written before the destruction of Jerusalem.

Among all the German commentaries on the first three Gospels, the best is that of Olshausen, English translation, Edinburgh, 1847. (On the whole subject of this article, see *An Introduction to the New Testament*, by Dr S. Davidson, vol. i., London, 1848.)

MATTHEW OF WESTMINSTER, a Benedictine monk of the abbey of Westminster, author of a Latin chronicle of great value, probably flourished during the early part of the fourteenth century, though some place him near the end of it. His work, which is said to have been formed very much upon the plan of that of Matthew Paris of the previous century, begins with the creation of the world, and continues to the death of Edward I. of England. In his preface he aspires to write the history of the whole world; but after the Heptarchy he is content to limit himself almost exclusively to Britain. After abridging the Bible in the early part of his work, he gives us a brief sketch of the history of Rome, with occasional reference to Greece; records the fabulous traditions of our own early times; tells the sad story of "old King Leyr;" relates the prophecy of Merlin; and so conducts the reader to the times of authentic history. Down to A.D. 1238 Matthew was much indebted to Roger of Wendover, whose chronicle stops at that date; but for the succeeding seventy-two years of his work he seems to have drawn entirely upon his own resources. After the Conquest his record of English affairs is exceedingly minute, and displays much industry and care; and in his relation of the wars of his own time, he displays a strong spirit of nationality, and striking powers of description. His narrative is ordinarily characterized by singular simplicity and directness, written with a careful eye to order and chronology, but filled with copious accounts of Romish miracles and other marvellous legends which, if not true, are at least sometimes amusing. With Hume and other modern historians he stands high as an authority on matters of fact. His chronicle is entitled *Flores Historiarum per Matthæum Westmonasteriensem collecti, præcipuè de rebus Britannicis, ab exordio Mundi usque ad annum Domini* 1307; folio, London, 1570. It was translated into English, by C. D. Yonge, for Bohn's Antiquarian Library, in 2 vols. 8vo, London, 1853.

MATTHEW, ST, an uninhabited island, situated off the western coast of Lower Siam, belonging to the Burmans. Long. 97. 30. E., Lat. 9. 35. N.

MATTHISSON, FREDERIC VON, a celebrated German lyric poet, was born at Hohendodeleben, near Magdeburg, in January 1761. As his father had died shortly before his birth, he was brought up by his grandfather, the Protestant minister of his native village. He attended the school of Klosterbergen, and studied theology at the university of Halle; but a decided bias for literature and philology induced him to abandon his intention of entering the church, and to become a private tutor. After residing in this capacity at Altona, Heidelberg, and Mannheim, he sojourned for two years on the Lake of Geneva, beside his friend the philosopher Bonstetten. He was then intrusted with the education of a merchant's son at Lyons. In 1792 Matthisson returned to his native country; and in 1794 he was appointed reader to the reigning princess of Anhalt-Dessau. In this capacity he spent the next fourteen years in visiting Italy, the Tyrol, and part of Switzerland. On the death of the princess in 1812 he entered the service of the King of Würtemberg, and was soon loaded with titles and honours. Following in the train of Duke William of Würtemberg, Matthisson again visited Italy in 1819, and lived for several months at Florence. He died at Wörlitz, near Dessau, in March 1831.

Among his countrymen Matthisson is a great favourite. His lyrics abound in tender sentiments and sweet rural pictures expressed in felicitous and harmonious verse. One of his pieces ("Adelaide") has been rendered doubly charming by the music of Beethoven. As a prose writer Matthisson is known by his *Erinnerungen*. He also published selections from the lyrical poetry of Germany, entitled *Lyrische Anthologie*, in 20 vols., Zurich, 1803-7. An edition of his works appeared in 6 vols., Zurich, 1825-29.

MATTO GROSSO, or **MATO GROSSO**, a province of Brazil, lying between Lat. 7. and 24. S., Long. 50. and 62. W., and bounded on the N. by the provinces of Para and Alto Amazonas, on the E. by that of Goiaz, on the S. by that of Parana, and on the W. by Bolivia; area estimated at 426,500 square miles. Of this extensive country little is known with accuracy, for it has been but little visited by Europeans, being covered to a great extent with dense forests, from which the province derives its name. It is traversed by several ridges of mountains, but these are of no great elevation. Great part of the surface is occupied by undulating table-lands. The principal mountain ridge runs from E. to W., and afterwards N.W., separating the waters that flow into the La Plata from those which go to swell the giant stream of the Amazon. This chain is known by different names in different places; being called the Serra dos Vertentes on the E., and the Parexis or Paricis on the W. and N.W.; while the whole bears the name of Cordillera Geral. Besides this, there are numerous branches from the central ridge in both directions, many of which have no distinctive names. The table-land on the N., which is called Canipos dos Paricis, is barren, and uninhabited by Europeans; while that of the Parana to the S. possesses large pastures. The principal rivers of the province are,—the Madeira and its tributary the Guaporé, the Juruenna, the Chingua, and the Araguaia, flowing to the N., and joining the Amazon and the Tocantins; and, flowing to the S., the Paraguay and the Cuiba. In many parts of the province gold and diamonds have been found; a circumstance which has induced the formation of settlements and mines; but these are now comparatively unproductive, and little cared for. Besides this, various other gems and minerals are found in different parts. Rock-salt and saltpetre are found, but they are not worked to any great extent; and although rich iron exists in great abundance, yet this metal has not attracted so much attention as the gold and precious stones, and is allowed to lie neglected. In many of the valleys the soil is very rich and fertile, producing rice, millet, cotton, sugar, tobacco, &c.; but comparatively little of the district is cultivated, owing to the thinness of the population. The natural productions of the country consist of timber of many different kinds, some of which are used for ornamental purposes; and gums, balsams, cacao, jalap, &c. Among the fauna of this country the principal are pumas, jaguars, deer, hares, &c. The climate is hot and tropical; and the rainy season extends from April to September, during which time the rivers overflow their banks, and fertilize the low-lying country in the neighbourhood. The inhabitants are chiefly native Indians; and they are occupied for the most part in hunting and pastoral employments. The commerce of the province is very small, and cannot be expected to make much progress as long as there are not better means of communication than at present exist. Mato Grosso is divided into two comarcas,—Cuiaba and Mato Grosso. It sends two members to the legislature of Brazil,—one to the Senate, and one to the Chamber of Deputies; and is governed by a provincial assembly of twenty members. The capital is Cuiaba, which, though a mere village, is the residence of an archbishop. The town of Mato Grosso, which was formerly called *Villa Bella*, is situated in the midst of wide plains on the Guaporé, and consists of low, wooden, tiled houses, which are arranged with considerable regularity. It contains churches and other public buildings, and has a population of 15,000. In the vicinity there are several mines. Pop. of the province, 180,000.

MATURIN, Charles Robert, a poet and romance writer, was born at Dublin in 1782, of a family of French extraction. After completing his education at Trinity College in his native city, Maturin took orders, and became a clergyman of the Established Church of Ireland, with the curacy of St Peter's for his preferment. His leisure hours were divided between the irksome duties of a classical tutor, by which he managed to augment his scanty income, and the much more congenial occupation of romance composition. He came before the public for the first time in 1807 as the author of a novel entitled *Fatal Revenge, or the Family of Montorio*, written in a terrific and gloomy style, after the manner of Monk Lewis, displaying some genius and much bombast, and strongly dashed with the mysterious colouring of the *Castle of Udolpho*. Having enjoyed considerable popularity by his efforts as a novelist, Maturin next directed his efforts to dramatic composition, and produced in 1816 a wild and powerful tragedy named *Bertram*, which, through the influence of Lord Byron and Sir Walter Scott, was performed at Drury Lane, where it met with surprising success. The Scottish novelist spoke of it as "one of those things which will either succeed greatly or be damned gloriously, for its merits are marked, deep, and striking, and its faults of a nature obnoxious to ridicule." Elated by his success, and rendered extravagant in his expectations by the L.1000 whch he realized through his tragedy, Maturin forgot to be provident, and plunged himself into inextricable embarrassments, from which the generous liberality of Scott and others could not rescue him. He prosecuted his literary projects, however, but found that to be haunted by bailiffs was not favourable for the development of his genius. His tragedy of *Manuel* accordingly, which appeared during the ensuing year, proved a very inferior production: "The absurd work," as Byron said, "of a clever man." Maturin continued his efforts in romantic fiction; and in addition to *The Milesian Chief*, and *The Wild Irish Boy*, previously published under the assumed name of "Dennis Jasper Murphy," he wrote *Women, or Pour et Contre*, and *Melmoth the Wanderer*, the wildest of his romances. The hero, a sort of absurd Dr Faustus, lives a century and a half, and by the help of the devil performs all manner of incredible adventures. The school of Ann Radcliffe reaches the culmination of loathsome horror and sickening extravagance in the person of this demoniac hero of Maturin's. "Eva," in *Women*, is the most simple and truthful of this author's delineations. *The Albigenses*, his last work, published in 1824 in 4 vols., proved tedious and uninteresting, possessing many of the defects of his previous works, and few of their excellences. His characters want variety, his humour is clumsy, and he has no genius for plot; yet his works display scenes of deep passion and touching pathos, coloured with the rich lights of a poetical imagination. In addition to the works already mentioned, Maturin published a tragedy called *Fredolpho*; a poem on *The Universe*; and a volume of sermons, London, 1819, characterized by much of the eloquence he is said to have possessed as a preacher. He died on the 30th October 1824.

MATY, Matthew, M.D., was born at Montfort, near Utrecht in Holland, in the year 1718. He was the son of a clergyman, and was originally intended for the church; but having turned his attention to physic, he took his degree of Doctor at Leyden, and in 1749 came to settle in England, where he secured the patronage of Lord Chesterfield. Maty began in 1749 to issue in French an account of the productions of the English press, printed at the Hague, under the name of the *Journal Britannique*,—a publication which continues to hold its rank amongst the best of the kind which have appeared since the time of Bayle. In 1758 he was chosen fellow of the Royal Society; and in 1765 he was appointed secretary to that eminent institution. He was also chosen principal librarian of the British Museum on the death of Dr Knight in 1772. He died after a lingering illness, August 2, 1776. He was an early and an active advocate for inoculation; and when there was a doubt entertained that one might have the small-pox even after inoculation, he tried it upon himself unknown to his family. Dr Maty's principal works were:—*Mémoire sur la Vie et sur les Ecrits de M. Ab. de Moivre*, 12mo, Hague; *Authentic Memoirs of the Life of Richard Mead, M.D.*, 8vo, London, 1755. His unfinished *Memoirs of the Earl of Chesterfield* were completed by his son-in-law, Mr Justamond, and prefixed to that nobleman's *Miscellaneous Works*, in 2 vols. 4to, 1777.

MAUBEUGE, a town of France, department of Nord, is situated on the Sambre, not far from the frontiers of Belgium. The town is well fortified, the defences being by the famous Vauban; and it has a manufactory of arms, founded by Louis XIV. in 1704. Maubeuge also has manufactures of ironmongery, cutlery, soap, &c.; and a considerable trade in coal, marble, and slates. The town traces its origin back to the seventh century, when an abbey was founded here by St Aldegonde. Situated near the frontier, this town has been an object of great contention, and has been taken no less than ten times since the fifteenth century, and finally by the Allies in 1815. Pop. 7328.

MAUCH CHUNK, a town in the state of Pennsylvania, North America, capital of Carbon county, is situated on a creek of the same name on the Lehigh River, 100 miles N.E. of Harrisburg. The surrounding country, though barren, is rich in coal and iron, which supplies Mauch Chunk with the most of its trade. The principal coal mines are about 9 miles W. of the town, and are reached by a railway. The original town is built in a narrow ravine near the river; but a new town is now rising on the top of the hill to the E. It contains a court-house, and other public buildings. Pop. (1850) 3500.

MAUCHLINE, a small town of Scotland, county of Ayr, is situated on an eminence not far from the River

Ayr, 7 miles S.E. of Kilmarnock, and 12 E.N.E. of Ayr. The town is well built, and contains an Established, a Free, and a United Presbyterian church, several schools, a public library, a savings-bank, and other institutions. The inhabitants are employed in weaving, shoemaking, and the manufacture of wooden snuff-boxes, for which Mauchline is famous. The river is crossed in the neighbourhood by several bridges, one of which, at Barskimming, is a structure of great elegance, consisting of a single arch 100 feet wide and 90 feet high. In the vicinity stands Mauchline Castle, an ancient edifice formerly in the possession of the Loudon family, who bear the title of Viscount Mauchline; and on Mauchline green there is a stone which commemorates the death of five Covenanters in 1685. But Mauchline derives its chief celebrity from being associated with the name of the poet Burns, who spent nine years of his life at the farm of Mossgiel in the neighbourhood. Pop. (1851) 1449.

MAULE, a river of Chile, rises in the Andes near the peak of Descabezado, and flows for 150 miles W. to the Pacific. It is navigable for a considerable part of its course; but it is obstructed by a bar at the month, where the surge is generally very violent. The principal tributary of the Maule is the Guanutil.

The province of the same name is bounded by this river on the N., and extends southward to the Itata, occupying a tract of ground of an undulating and hilly nature. It is productive of grain, wine, and tobacco, and affords excellent pasturage for cattle, in the rearing of which the inhabitants are chiefly employed. There is some trade in the exportation of wines and tobacco. The principal towns are Cauquenes, the capital; Constitucion, at the mouth of the Maule; and others. Pop. 118,309.

MAUMEE, a river of the United States of North America, is formed by the confluence of the St Joseph's and St Mary's Rivers at Fort Wayne, in the state of Indiana. It flows in a N.E. direction through that state and Ohio, till it falls into Maumee Bay, at the W. extremity of Lake Erie, after a course of 100 miles. It is navigable through all its extent for boats, and for steamers as far as Defiance, 60 miles up. The Wabash and Erie Canal extends along the banks through the whole course of the river.

MAUNDAY THURSDAY (called also *Shere Thursday*) is the Thursday immediately preceding Easter, on which a certain number of poor persons receive alms from the king or queen. Some conceive the name Maunday to be derived from *mandatum*, command; but others with stronger probability suppose it to be derived from the *maunds*, or large baskets from which it was customary to distribute the alms to the poor. It received the name "Shere Thursday," says an old homily, "for that in old Fathers' days the people would that day shere theyr hedes and clypp theyr berdes, and so make them honest agenst Easterday." The ceremonial of the Maunday, as practised by Queen Elizabeth in 1572, was as follows:—After thirty-nine poor people (the number equal to the years of her majesty's age) had been placed on forms by a long table in a hall prepared for the occasion; and after the preliminary arrangements had been gone through, "her majesty came into the hall, and after some singing and prayers made, and the gospel of Christ's washing of his disciples' feet read," her majesty "kneeling down upon the cushions and carpets under the feete of the poore women, first washed one foote of every one of them in soe many several basons of warm water and swete flowers, then wiped, crossed, and kissed them, as ther almoner and others had done before." Then after receiving food, clothing, and money from the queen, they retired. The last king who performed this ceremony in person was James II. We learn from the *Times* newspaper of April 16, 1838, that after the distribution of the queen's royal alms, which consisted of money and clothing, to the Maunday men and women, by Mr Hanby, at the Almonry Office, "they also received L.1, 10s., a commutation *instead of the provisions heretofore distributed.*" Nor was this custom confined to the sovereign; for we find that Cardinal Wolsey in 1530 "made his Maundy;" and in the Earl of Northumberland's household book of 1512, we have an enumeration of "al mauner of things yerly yeven by my lorde of his Maundy." The same ceremony is kept up in German Catholic countries by the court, under the name of *Fusswaschung*, or "the washing of the feet;" and Dr E. D. Clarke (*Travels in Russia*, 1810, i. 55) witnessed "the Archbishop of Moscow washing the feet of the apostles" on the Thursday immediately preceding Easter. (Brand's *Popular Antiquities*, vol. i., p. 142.)

MAUPERTUIS, Pierre-Louis Moreau de, a celebrated French academician, was born at St Malo in the year 1698. At the age of sixteen he was placed under the eminent professor of philosophy M. le Blond, in the college of La Marche at Paris, where he displayed a peculiar aptitude for mathematical studies, and particularly for geometry. He entered the army at the age of twenty, and first served in the Gray Musqueteers; but in the year 1720 his father purchased for him a company of cavalry in the regiment of La Roche-Guyon. He remained only five years in the army, during which time he pursued his mathematical studies with great vigour and success. In the year 1723 he was received into the Royal Academy of Sciences, and read his first performance, which was a memoir upon the construction and form of musical instruments (15th November 1724). During the first years of his admission he did not wholly confine his attention to mathematics; he likewise turned his attention to natural philosophy, and made ingenious observations and experiments upon animals. Maupertuis made a pilgrimage to the country which gave birth to Sir Isaac Newton; and during his residence in London he became as zealous an admirer and follower of that philosopher as any one of his own countrymen. On his return, he visited Basle in Switzerland, where he formed a friendship with John Bernoulli which continued till his death. Returning to Paris, he applied himself to his favourite studies with greater zeal than ever, of which abundant evidence is to be found in the Memoirs of the Academy from the year 1724 to 1736. The most sublime questions in geometry and the relative sciences were handled with that peculiar elegance, clearness, and precision, so remarkable in all his writings. In the year 1736 he was sent by the King of France to the polar circle to measure a degree of the meridian, in order to ascertain the figure of the earth, accompanied by MM. Clairaut, Camus, Le Monnier, the Abbé Outhier, and Celsius the celebrated professor of astronomy at Upsal. This distinction rendered him so famous that at his return he was admitted a member of almost every academy in Europe. In the year 1740 Maupertuis received an invitation from the King of Prussia to go to Berlin, which was too flattering to be refused. Having followed his Prussian majesty into the field to witness the battle of Mollwitz, his horse, during the heat of the action, ran away with him, and falling into the hands of the enemy, he was carried prisoner to Vienna, where he received distinguished honours from their imperial majesties. On his return to Paris, Maupertuis was in 1742 chosen director of the Academy of Sciences. In 1753 he was received into the French Academy, which was the first instance of the same person being at the same time a member of both the academies at Paris. He again assumed the character of a soldier at the siege of Fribourg, and was employed, on the surrender of that citadel, to carry the news to the French king. Having in 1744 married Mademoiselle de Borck, a lady nearly related to M. de Borck, then minister of state at the court of Berlin, Maupertuis took up his residence at that city. In the year 1746 he was chosen president of the Royal Academy of Sciences at Berlin; and soon afterwards was honoured with the Order of Merit. However, all these accumulated honours and advantages only furnished new allurements to labour and application. Nor did he confine himself solely to mathematical studies; metaphysics, chemistry, botany, polite literature, all shared his attention, and contributed to his fame. At the same time his temper was none of the best, and he had the misfortune to be engaged in several quarrels. He had a dispute with Koenig, the professor of philosophy at Franeker, and another of a more serious kind with Voltaire. The former unjustly charged Maupertuis with plagiarizing from Leibnitz; and the latter, with his accustomed wit and satire, espoused the cause of the German professor. The dispute became so serious that Maupertuis found it expedient in 1753 to quit the court of Prussia. Maupertuis's constitution had long been considerably impaired by the fatigues of various kinds in which his active mind had involved him; indeed, to the amazing hardships he had undergone in his northern expedition most of his future bodily sufferings may be traced. Yet his mind seemed still to possess the greatest vigour; for the best of his writings were produced, and his most sublime ideas developed, during the time of his confinement by sickness, when he was unable to occupy his chair as president at the academy. He took several journeys to St Malo in quest of health; and after visiting Toulouse and Neufchatel, he at length arrived at Basle on the 16th of October 1758, where he was received by his friend John Bernoulli and his family with the utmost tenderness and affection. He at first found himself much better there than he had been at Neufchatel; but this amendment was of short duration; for, after languishing here many months, he died in 1759.

The works of Maupertuis were collected into 4 volumes 8vo, and published in 1756 at Lyons, where a new and elegant edition was also printed in 1768. These consist of—*Essai de Cosmologie*, first published at Berlin in 1748; *Discours sur la Figure des Astres*, first published in 1732; *Essai de Philosophie Morale*, in which he maintains that the sum of evil surpasses that of good; *Réflexions Philosophiques sur l'Origine des Langues et la Signification des Mots*; *Venus Physique, or an Exposition of the System of Generation*; *Système de la Nature*, first published in 1751, and which may be considered as the sequel of the preceding work; *Lettres*, on various subjects; *Eléments de Géographie*, published at Paris in 1742, and containing an exposition of the means for determining the figure of the earth; *Relation d'un Voyage fait par ordre du Roi au Cercle Polaire*, printed at Paris as early as 1738; *Relation d'un Voyage au fond de la Laponie*; *Lettre* on the Comet of 1742; *Discours Académiques*, pronounced in the French and Prussian Academies; *Mémoire sur la moindre quantité d'Action*; *Astronomie Nautique*, a work much praised when it first appeared, but now little read; *Parallaxe de la Lune*; *Mésure du Degré du Nord*. Besides these treatises, Maupertuis was the author of a great number of papers, printed partly in the Memoirs of the French Academy of Sciences, and partly in those of the Academy of Berlin.

MAURETANIA, an ancient kingdom of Africa, bounded on the W. by the Atlantic Ocean, on the S. by Getulia or Libya Interior, and on the N. by the Mediterranean, and comprehending the greater part of the kingdoms of Fez and Morocco. Its ancient limits are not exactly mentioned by any historian; nor can they now be ascertained by modern observations, these kingdoms being but little known to Europeans.

This country was originally inhabited by a people called *Mauri*, concerning the etymology of whose name authors are not agreed. It is probable, however, that the country, or at least great part of it, was first called *Phut*, since it appears from Pliny, Ptolemy, and St Jerome, that a river and territory not far from Mount Atlas went by that name. It likewise appears, from the Jerusalem Targum, that part of the Mauri may be deemed the offspring of Lud, the son of Misraim, since his descendants, mentioned in Genesis, are there called *Mauri*, or *Mauritani*. It is certain that this region, as well as the others to the eastward of it, had many colonies planted by the Phœnicians. Procopius tells us that in his time two pillars of white stone were to be seen containing the following inscription in the Phœnician language and character:—"We are the Canaanites who fled from Joshua the son of Nun, that notorious robber." Ibnu Rachic, or Ibnu Raquig, an African writer cited by Leo, and also Evagrius and Nicephorus Callistus, make the same statement.

The Mauretanians were, according to Ptolemy, divided into several cantons or tribes. The Metagonitæ were situated near the Straits of Hercules, now those of Gibraltar; the Saccosii, or Cocosii, occupied the coast of the Iberian Sea; and under these two petty nations the Masices, Verues, and Verbicæ or Vervicæ, were settled. The Salisæ or Salinsæ were situated lower, towards the ocean; and still more to the south were the Volubiliani. The Maurensii and Herpiditani possessed the eastern part of this country, which was terminated by the Mulucha. The Angaucani or Jangacaucani, Nectiberes, Zagrensii, Baniubæ, and Vacuntæ, extended from the southern base of Ptolemy's Atlas Minor to his Atlas Major. Pliny mentions the Baniuræ, whom Father Hardouin takes to be Ptolemy's Baniubæ; and Mela speaks of the Atlantes, whom he represents as possessing the western part of this district.

The earliest Prince of Mauretania mentioned in history is Neptune; and next to him were Atlas and Antæus his two sons, both famous in the Grecian fables on account of their wars with Hercules. Antæus, in his contention with that hero, seems to have behaved with great bravery and resolution. Having received reinforcements of Libyan troops, he cut off numbers of Hercules's men. But that celebrated commander, having at last intercepted a strong body of Libyans sent to the relief of Antæus, inflicted on him a total overthrow, in which both he and the greater part of his forces were put to the sword. This decisive action put Hercules in possession of Libya and Mauretania, and consequently of the riches of these kingdoms. Hence arose the fable that Hercules, finding that Antæus, a giant of enormous size with whom he was engaged in single combat, received fresh strength as often as he touched his mother earth when thrown upon her, at last lifted him up in the air and squeezed him to death. Hence likewise may be deduced the fable which intimates that Hercules took the globe from Atlas upon his own shoulders, overcame the dragon which guarded the orchards of the Hesperides, and made himself master of all the golden apples it produced, which were probably the treasures which fell into Hercules's hands upon the defeat of Antæus; the Greeks giving to the oriental word מאל, *riches*, the signification affixed to their own term *μηλα*, *apples*.

With regard to the age in which Atlas and Antæus lived, the supposition of Sir Isaac Newton seems to be the most probable. According to that illustrious author, Ammon, the father of Sesak, was the first King of Libya, or of that vast tract extending from the borders of Egypt to the Atlantic Ocean, the conquest of which country was effected by Sesak in his father's lifetime. Neptune afterwards excited the Libyans to a rebellion against Sesak, and slew him, and then invaded Egypt under the command of Atlas or Antæus, the son of Neptune, Sesak's brother and admiral. Not long after, Hercules, the general of Thebais and Ethiopia, reduced a second time the whole territory of Libya, having overthrown and slain Antæus near a town in Thebais, from that event called *Antæa* or *Antæopolis*. This happened about a thousand years before the birth of Christ.

From the defeat of Antæus nothing remarkable occurs in the history of Mauretania till the times of the Romans, who at last brought the whole kingdom under their jurisdiction. With regard to the customs and manners of this people, it would seem, from what Hyginus insinuates, that they fought only with clubs, until one Belus, the son of Neptune (as that author calls him), taught them the use of the sword. Sir Isaac Newton is of opinion that this Belus was the same with Sesostris, King of Egypt, who overran a great part of the then known world. All persons of distinction in Mauretania went richly attired, wearing gold and silver on their clothes, and bestowed great care on the ornamenting of their persons. The Mauretanian infantry in time of action used shields made of elephants' skins, being clad in those of lions, leopards, and bears, which they kept on both night and day. The cavalry of this nation were armed with broad, short lances, and carried targets or bucklers made of the skins of wild beasts. They used no saddles. Their horses were small and swift, had wooden collars about their necks, and were so much under the command of their riders that they followed them like dogs. The habit of these horsemen was not much different from that of the foot already mentioned; they constantly wore a large tunic of the skins of wild beasts. The Phutæi, of whom the Mauretanians were a branch, were eminent for their shields, and the excellent use they made of them, as we learn from Homer, Xenophon, Herodotus, and Scripture. Nay, Herodotus seems to intimate that the shield and helmet came from them to the Greeks.

Notwithstanding the fertility of their soil, the poorer sorts of the Mauretanians never took care to manure the ground, being strangers to the art of husbandry, but roved about the country in a wild and savage manner, like the ancient Scythians or *Arabes Scenitæ*, living in tents, or *mapalia*, inconveniently small. Their food was corn, herbage, &c., which they frequently ate green without any manner of preparation, being destitute of wine, oil, and all the elegancies as well as many necessaries of life. Their habit was the same both in summer and winter, consisting chiefly of a coarse, thick garment, and over it a rough tunic, which answered probably to that of their neighbours the Numidians. Most of them lay every night upon the bare ground, not unlike the Kabyles and Arabs of the present day. If the most approved reading of Horace may be admitted, the Mauretanians shot poisoned arrows, which clearly intimates that they had some skill in the art of preparing poisons, and were excellent bowmen. This last observation is countenanced by Herodian and Ælian, who affirm that they were in such continual danger of being devoured by wild beasts, that they durst not stir out of their tents without their darts. Such perpetual exercise must have rendered them exceedingly skilful in hurling that weapon. The Mauretanians sacrificed human victims to their deities, like the Phœnicians, Carthaginians, and other nations. The country people were extremely rude and barbarous; but those inhabiting cities must have had at least some acquaintance with the literature of the several nations from whom they derived their origin. That the Mauretanians had some knowledge of naval affairs seems probable, not only from the intercourse they had with the Phœnicians and Carthaginians, as well as the situation of their country, but likewise from the statement of Orpheus or Onomacritus, who asserts that they had made a settlement at the entrance into Colchis, to which place they came by sea. To magic and sorcery, divination and witchcraft, they appear to have applied themselves in very early times. Cicero and Pliny say that Atlas was the inventor of astrology and the doctrine of the sphere, which he first introduced into Mauretania. This, according to Diodorus Siculus, gave rise to the fable of Atlas bearing the heavens upon his shoulders. The same author relates that Atlas instructed Hercules in the doctrine of the sphere and astrology, or rather astronomy, and that the latter afterwards brought these sciences into Greece.

MAURICE, THOMAS, a learned oriental historian, the son of the head master of Christ's Hospital school in Hertford, was born at that town about 1753. By his father's death he was left at an early age to the care and tuition of Dr Parr, then master of an academy at Stanmore. In his nineteenth year he repaired to Oxford, and was enrolled at St John's College, but subsequently removed to University College. There he produced a metrical version of *Œdipus Tyrannus*, and several original poems; and began to cultivate, under his tutor, Lord Stowell, that taste for historical research which afterwards led him into notice. After graduating as B.A. he was appointed curate of Woodford in Essex, a charge which he resigned in 1785 for a smaller pastorate at Epping. His *Indian Antiquities* began to appear in 1791, and was completed in 7 volumes in 1797. *The History of Hindustan*, his other great work which he had commenced to publish in 1795, was finished in 3 volumes in 1799. Meanwhile, Earl Spencer had appointed him in 1798 to the vicarage of Wormleighton in Warwickshire. In 1799 Maurice was installed assistant librarian to the British Museum; and in the following year he received the pension left vacant by the death of Cowper. The 2 volumes of his *Modern History of India* appeared in 1802 and 1804 respectively. In this latter year he was presented by the Lord Chancellor to the vicarage of Cudham in Kent. A second edition of his *History of Hindustan* appeared in 1821. He died in March 1824.

MAURICE *of Nassau*, the son of William I., Prince of Orange, was born in 1567, was elected stadtholder of the United Provinces in 1584, succeeded his brother as Prince of Orange in 1618, and died in 1625. (See HOLLAND.)

MAURICIUS, FLAVIUS TIBERIUS, Emperor of Constantinople, descended from an old Roman family, was born at Arabissus in Cappadocia about A.D. 539. His youth was spent in the camp; but as the sword was the only weapon of influence he could wield, he remained for a long time in obscurity. The sagacious Tiberius, however, on his accession to the throne in 578, discovered the eminent talents of the poor soldier of fortune, and appointed him to supersede Justinian in the conduct of the war against the Persians. Maurice repaired to the quarters of the army in Mesopotamia, and began his generalship by attempting to restore the severity of the old Roman discipline; then facing the enemy in the open field, he drove them out of Mesopotamia, and ended the first campaign by penetrating beyond the Tigris. After making a bold inroad into Media, he completely humbled the Persian power in two decisive battles, and in 582 entered Constantinople in triumph. In the same year Tiberius died, after bequeathing his crown to Maurice, and bestowing upon him the hand of his eldest daughter Constantina. Mature in age, and well-tried by experience, the new emperor began his reign amid the general rejoicing of his subjects. No sooner had he sat down on the throne, than the Persians, under their king Hormisdas, the son of Chosroes, revolted, and defeated John Mystacon, the general of the imperial forces. Other reverses in the following year induced Maurice in 584 to send out his brother-in-law Philippicus to supersede Mystacon. But this general, though at first successful in checking the inroads of the enemy, was at last defeated, and obliged to retreat in confusion. He was stripped of his command in 588 by the order of Maurice; but a dangerous revolt among the soldiers caused him to be restored to his former office, only to suffer another defeat and another degradation in 589. His successor, Comentiolus, would have fallen into the same mishaps had not Heraclius virtually assumed the command, and retrieved the Roman fortunes by the brilliant victory of Sisarbene. The rebellion against King Hormisdas in 590 withdrew the hostility of the Persians, and restored tranquillity to the Asiatic provinces. That tranquillity was confirmed by an event which happened in the subsequent year. Chosroes, the son of Hormisdas, driven into exile by Baram, the leader of the rebel

Persians, sought refuge in the Roman territory, and sent a letter to the emperor imploring assistance for the recovery of his ancestral throne. Moved by the deepest generosity, Maurice presented the royal fugitive with a diadem and a large sum of money, and sent him back, under the protection of a large army, to demand his father's sceptre. His entrance into Persia revived the loyalty of his subjects; and the insurgent Baram, deserted by nearly one-half of his troops, was completely routed at Balarath. Thus restored to his father's throne, Chosroes was ever afterwards a faithful friend of Maurice.

Scarcely had war been quelled in one part of the empire when it began to break out in another. The prowling hordes of the Avars, under their chagan or khan, had for some time menaced the European provinces, and had now become a scourge that could no longer be tolerated. Accordingly, Maurice threw off the sloth that had for two centuries been considered a necessary part of imperial state. He placed himself at the head of the entire force of the empire, set out on the march toward the hostile territory, and would have faced all the hardship and peril of the field, had not the remonstrances of his subjects, and some unfavourable omens, induced him to return to Constantinople. The command then devolved upon Priscus, and afterwards upon the emperor's brother Peter; but the latter proved weak and cowardly, and the former was restored in 598. Not so successful as was expected, Priscus was superseded in 600 by Comentiolus. This weak-minded and cowardly impostor was worsted by the enemy on every side. In one battle 12,000 Romans were captured, and greater misfortunes were impending, when the brave Priscus, resuming the command, defeated the Avars in five successive battles, and drove them before him as far as the Danube. Meanwhile Maurice, for some reason unknown, had refused to ransom the prisoners taken by the khan of Avars at the defeat of Comentiolus, and had left them to be butchered in cold blood. At this inhumanity a spirit of revenge had been excited among the pampered and self-willed soldiers of the imperial army, and only waited for an opportunity to vent itself in open revolt. This opportunity was now given by the infatuated emperor himself. In 602 he ordered his army to cross the Danube, and to winter in the Avarian territory. Crying out that they were now doomed to be butchered like their comrades, the soldiers threw off their allegiance, massacred the faithful adherents of the emperor, and placing Phocas, a centurion, at their head, hastened by forced marches towards Constantinople. The report that the army was approaching raised an insurrection in the capital; and Maurice, during a night of general rapine and consternation, escaped by sea with his wife and children, and took refuge in the church of St Autonomus, near Chalcedon. There the emissaries of Phocas soon afterwards found him bending under despair and bodily disease. They dragged him from his sanctuary, and murdered five of his sons while he stood by uttering pious ejaculations. He met his own fate with firmness on the 27th November 602. The bodies of the father and sons were thrown into the sea, and their heads were exposed on pikes in the streets of Constantinople.

The Emperor Maurice was a good man and a wise ruler. Strong self-command, an affectionate disposition, and sincere piety, marked his private conduct. His public authority was always exerted in lightening taxes, in enforcing beneficial laws, in patronizing art and learning, or in repelling foreign invasion. It was his misfortune to fall upon an age in which his economy was mistaken for avarice, and his military discipline for cruelty. A Greek treatise which he wrote on military science was translated into Latin, and published, along with Arrian's *Tactica*, by John Scheffer, Upsala, 1664, 8vo. There is a Life of Maurice by Theophylactus Simocatta, a writer of the seventh century.

MAURITIUS, or ISLE OF FRANCE, an island lying in the Indian Ocean, between 57. 17. and 57. 46. E. Long and 19. 58. and 20. 32. S. Lat. It lies 400 miles E. of the island of Madagascar, and 120 miles N.E. of the island of Bourbon, 2327 miles from the Cape of Good Hope, and 9500 miles from England *via* Suez and Aden. It extends from N. to S. 36 miles, from E. to W. 32 miles; comprising an area of 432,680 superficial acres, or 676 square miles. Its form is elliptical; the greatest diameter of the oval is 63,780 yards, and its breadth 44,248. The island is encircled by a belt of coral reefs, which makes the approach to it dangerous.

Mauritius is one of the most romantic and picturesque-looking islands in the Eastern Hemisphere. The northern is more elevated than the southern extremity; the land rises gradually from the shore to the interior. The centre of the island is intersected by a chain of mountains, with spurs radiating to the coast. There are three principal ranges of mountains, varying from 1800 to 2800 feet in height above the level of the sea, and for the most part covered with timber. The form of many of these mountains is grotesque and singular; the great chain called the Pouce, the summit of which is 2484 feet high, is so named from its supposed resemblance to the human thumb. On the same chain is a mountain called the Peterbote, 2520 feet in height, which has been frequently ascended, and is terminated by an obelisk or spire of naked rock, on the top of which reposes an immense globular mass of stone, larger than the point of the pyramid on which it is balanced. The mountains abound in curious caverns of considerable extent. Both the appearance of the island and the nature of its material indicate volcanic origin. In the centre of the island is an elevated plateau called Vaconas or Vacois, 1200 feet above the level of the sea; in the middle of this plain is a mountain of sugar-loaf form called Piton du Milieu, 1812 feet high. There are other mountainous ranges which slope down gently towards the sea, which are named Faience, Grand Port, Corps de Garde, Savanne, Rivière Noire, Rempart, and Pouce.

The Rivers Tamarin and Rempart run parallel to each other, receiving as affluents the lesser streams which flow around the Lake Vaconas. In the rainy season they are overwhelming torrents, which, in their course to the sea, form very beautiful cascades; in the dry season they are little more than brooks. The other rivers are the Latanier, Plain Wilhems, Moka, Great and Little Black River. One of the natural curiosities of the island is the lake called Mare aux Vaconas or Vacois, named from the vaconas (*Pandanus utilis*) by which it is encircled. It is surrounded by many acres of marshy and swampy ground, as its name implies, through which many streams, flowing into its centre, form a lake, which is well stocked with cray-fish, prawns, and eels of enormous size, and a small red fish called *damairie*, originally brought from China. Another freshwater lake is the Grand Bassin, a circle whose diameter is somewhat less than half a mile, surrounded by precipitous rocks rising perpendicularly from their base to a considerable height. In the most elevated of the central tracts, a league further E. than the Grand Bassin, is a lake called Mare aux Joncs.

Geologically the island presents all the appearances of volcanic origin. The rocks rise in strata from the shore to the centre of the island, upon whose plain stand out many rocky mountains composed of ferruginous rocks and a greyish lava, which, when decomposed, produce a soil of an argillaceous description, intermingled with oxide of iron. It has been surmised that there is some cavernous communication with the island of Bourbon, as the eruptions of its mountains are sensibly perceptible at Mauritius. From its volcanic formation, it abounds with numerous caverns, ravines, and rugged precipices. It contains some iron mines, which were once extensively wrought.

The climate is salubrious and agreeable, but at certain periods of the year rather hot. The heat, however, is moderated by the sea-breeze. At all times the temperature of the elevated districts, especially of Plain de Wilhems, is pleasant and refreshing, the thermometer varying from 70° to 80° Fahr.; while below, in Port Louis, it varies from 90° to 96°. There are four seasons at the Mauritius: the first commences in May, accompanied by rain and winds from the S.E.; the second with September or October;—the sun at this time approaching the zenith, causes squalls and winds till December, when the third season begins; this is terminated in March, when the fourth or last season commences, lasting about eight weeks. In the third season, namely, from December to March, the island is often visited by violent and most destructive hurricanes, accompanied by torrents of rain and gusts of wind, shifting round all the points of the compass, and causing great damage to the shipping, houses, and sugar plantations. These gales of wind last about eight hours; but of late years they have been less frequent and violent than heretofore, arising from the greater dryness of the atmosphere, in consequence of the island having been cleared of its forests.

The soil of this island is in many places very rich and fertile, of a reddish colour, highly impregnated with iron. The surface of the ground is covered with large stones, which render the use of a plough impracticable, so that it is prepared for crops by the hoe. In many districts of the island it is composed of mould, clay, and marshy plains, and is throughout generally highly productive and fertile. The chief, and it may be said the only, production of the island is sugar. Coffee and rice are grown, but in small quantities, not sufficient for the consumption of the colony. Indigo, cotton, and spices, have been successfully cultivated. An agricultural society was formed in 1853 at the Mauritius by the principal planters, with the view of improving the culture of the sugar-cane. Guano is extensively used as a manure, of which 25,707 tons were imported within the year 1856. The fertilizing power of this manure in the production of sugar is said to be almost fabulous, converting, as if by magic, sterile wastes into luxuriant plantations. The government botanical gardens at Pamplemouse are as remarkable for their varied productions as their beauty, wherein the rarest and richest plants of the East have been raised. In the vegetable and animal kingdoms there is not anything remarkable, with the exception of the fine ebony, and the dodo, a large unwieldy bird inhabiting only the Mauritius and Bourbon, but now wholly extinct.

The live stock of the island in 1854 consisted of 12,339 horses, 12,907 horned cattle, 17,076 sheep and goats. In 1854 the extent of land under each kind of crop was,—sugar-cane, 92,277 acres; maize, 6082; manioc, 5154; potatoes, 248; coffee, 125; fruits and vegetables, 8841: total in crops, 167,989 acres. Of forest land, 66,790 acres; pasture, 52,390 acres; uncultivated, 54,390. It may be observed that the staple produce of the colony is sugar. The total export of sugar in 1855 was 102,000 tons; indicating a steady and considerable annual increase. The exportation of tortoise-shell was 1648 lb.; of ebony, coffee, cloves, cotton, indigo, so small as to be scarcely worth notice. The principal imports consist of provisions and grain; cattle and rice from Madagascar and India; horses from the Cape of Good Hope; ponies from Batavia; mules from France and Spain; sheep from Bombay and the Cape of Good Hope. Earthenware, machinery, furniture, hardware, piece goods, wines, &c., are largely imported. The total estimated value of imports in 1854 was L.1,492,788; of exports for the same year, L.1,246,400. The following table exhibits a view of the import and export trade of Mauritius, as carried on with Great Britain, the British Colonies, America, and other countries, during the year 1854:—

Amount of Shipping in 1854.

	INWARDS.			OUTWARDS.		
	Ships.	Tons.	Men.	Ships.	Tons.	Men.
Great Britain.......	64	299,669	1,461	167	60,178	3,015
British Colonies ...	287	112,120	7,863	213	89,046	6,547
United States	2	1,350	39	...	...	...
Other foreign states	223	5,240	...	192	46,478	3,198
Total.........	576	418,379	9,363	572	195,702	12,760

Two lighthouses have been completed,—the main light on Flat Island, with a subsidiary one at Cannonier Point. Two mast-lights have also been erected to guide ships into the harbour. A new road has been constructed leading from Mahebourg through the valley of the Cent Gaulettes, connecting Grand Port and Moka, which will shorten the distance between the two capitals of the island 5 or 6 miles, passing by the Piton du Milieu de l'Isle, through the forest of Trois Islots and Moka, opening up large tracts of virgin land hitherto untilled and inaccessible. The main roads of the colony repaired by government are good; but the bye roads, from inefficient management, are in a very unsatisfactory condition. At present no railroads or canals have been constructed.

The government of the island, as at present constituted, is vested in a governor, aided by an executive council, of which the colonial secretary, procureur or advocate-general, and the second officer in command of Her Majesty's troops, are *ex officiis* members. There is also a legislative council, consisting of seven official and seven non-official members; the former comprising the three executive members above spoken of, and the collector of customs, auditor-general, treasurer and collector of internal revenues; the latter seven non-official members are chosen from the chief landed proprietors of the island, and submitted to Her Majesty in council for approval and confirmation. By the 8th article of the capitulation it was stipulated that the inhabitants should preserve their religion, laws, and customs; and by virtue of this provision the authority of the Code Civile, the Code de Procédeure, the Code du Commerce, and the Code d'Instruction Criminelle, except in so far as altered by the charter of justice of April 13, 1831, have since been recognised in the island. By that charter a court of appeal was reconstituted, and a supreme court of civil and criminal justice established, presided over by three justices. There is also a petty court, from which there is no appeal, for the trial of trivial crimes and offences.

The total revenue amounted in 1855 to L.348,452; the expenditure to L.317,839; leaving a surplus revenue of L.30,613. There has accumulated during the last five years an aggregate surplus revenue of L.161,915, showing that the finances of the colony are in a very satisfactory condition.

With respect to the religious and educational condition of the colony, considerable progress has been made of late years; but much remains yet to be done before it can be considered to be in a satisfactory state. There is at Port Louis, the capital of the island, a royal college, attended on an average by 284 scholars, and the fees paid by them amount to L.2587. The total cost of this establishment in 1855 was L.4129, L.1600 of which is contributed by government. The annual grant estimated for schools in 1857 is L.8788, exclusive of the royal college grant, which amounts to L.7016; the expense of sending two pupils to England, instead of one, accounting for the increase when compared with grants of former years; There are at the government schools 1860 scholars; at private schools, 2235; at the schools of the Christian Knowledge Society, 89; at the Roman Catholic schools, 908. The religious condition of the colony is not favourably reported of by the recently appointed Protestant bishop. There are but six clergymen of the Established Church, and two ministers of Protestant denominations; while the Church of Rome

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has provided a bishop and thirteen priests paid out of the colonial treasury. The great influx of heathen population, introduced into the colony by the employment of coolies from India, and the unequal immigration of the sexes, have tended very much to demoralize the social condition of the island. A newspaper of the Mauritius, dated Nov. 3, 1853, thus comments on this evil state of society:—"The third criminal assizes of this year commenced on the 17th of October. The calendar presented an alarming amount of crime on the part of the Indian population, and some instances of great atrocity. The most fearful social consequences must ensue upon any long-continued neglect of the moral and religious welfare of this immense branch of our population."

The island is divided into nine districts, namely, Port Louis, Pamplemouse, Flacq, Rivière du Rempart, Grand Port, Savanne, Moka, Plain de Wilhems, and Black River. The Mauritius was discovered by the Portuguese in 1507, called by them *Ilha do Cerné*, supposing it to be the *Cenne* of Ptolemy. They kept possesssion of it nearly the whole of the sixteenth century. The first who made any settlement in it were the Dutch, in the year 1598, when they changed the name from Cerné to *Mauritius*, in honour of their Prince Maurice. Being occupied in the pursuit of wealth in the East, it was abandoned by them in 1710, and was afterwards taken possession of by the French in 1721, who called it *Ile de France.* The first regular settlement took place in 1735 under Monsieur de la Bourdonnais, who introduced manufactures and the culture of the sugar cane, cotton, and indigo, and engaged himself in raising public edifices, making roads, and clearing the forest with which the island, when first visited, was covered. Upwards of half a century elapsed before the French duly appreciated the value of their new acquisition, the foundation of its prosperity having been laid by the governor above named, who fixed a port on the N.W. of the island as the seat of its present capital, Port Louis. He was succeeded by Monsieur de Poivre, who, notwithstanding the jealousy of the Dutch, brought from the distant isles in the Eastern Archipelago, and introduced into the colony, the clove, nutmeg, and various other spice trees. The Isle of France was for a long time during the war a source of great mischief to our merchant vessels and Indiamen. The position of the island in the eastern seas, and the facility with which sorties might be made from it upon our traders by French men-of-war and privateers, determined the British government upon an expedition for its capture, which was effected in 1810. At the peace in 1814 the possession of the island was ratified, since which the Mauritius has continued annexed to the British Empire.

The population of the Mauritius and its various dependencies, consisting of different races and every conceivable form of admixture springing from these, amounted, by the census taken in 1851, to 120,331 males, 61,482 females; of whom, in 1854, 60,350 were employed in agriculture, 5322 in manufactures, and 5419 in commerce. The number of births in 1854 was 5683; deaths, 14,398; marriages, 610.

The island of Rodrigue, the Seychelles Islands, Diego Garcia, and others belong to Mauritius. Rodrigue is situated about 300 miles to the eastward of Mauritius, in S. Lat. 19. 13. It is 26 miles in length by 12 in breadth, and consists of a succession of verdant hills. Although the valleys are almost full of rocks and stones, there still remains a considerable portion of fertile soil, which is cultivated by colonists from the Mauritius. The vegetation is luxuriant, the climate salubrious, and the water clear. There is abundance of fish around the island, but some of them are poisonous at certain seasons, when feeding on the coral plant. The Seychelles or Mahé Islands are situated between the parallels of S. Lat. 4. and 5. There is nothing interesting regarding their history. The lepers from the Mauritius are sent to Mahé. When Mauritius capitulated to Britain they were taken possession of as a dependency of that colony, which keeps there a civil commissioner, assisted in his duties by subordinates. There is a petty civil and criminal court held for trial of causes and offences. The social condition is not favourably reported of by the present commissioner in his report to the governor of the Mauritius. This dependency is a great expense to the colony of Mauritius.

Mauro.

The names of the principal islands, with the number of acres in each, are as under:—

Names.	Acres.	Names.	Acres.
Mahé	30,000	Marianne	250
Praslin	8,000	Conception	120
Silhouette	5,700	Felicity	800
La Digue	2,000	North Island	500
Curieuse	1,000	Denis	200
St Anne	500	Vache	200
Cerf	400	Aride	150
Frigate	300		

Total number of acres, 50,120.

There are a number of other smaller islands, all resting on an extensive bank of sand and coral, which also surrounds them to a great extent. Mahé, the principal island and seat of government, is 16 miles in length, and from 3 to 5 in breadth, with a very steep and rugged granite mountain running through the centre. The vegetation on this, as well as on many others of the group, is extremely luxuriant; and amongst their productions are various spices, such as the cinnamon, clove, &c. The town of Mahé is situated on the N. side of the island; its population has varied very little for the last thirty years, and may be estimated at about 7000. These dependencies are visited by whaling vessels for water, hogs, goats, &c., with which some of the uninhabited islands abound. The most remarkable vegetable production is the *coco de mer*, so called because the nuts were found on the coast of Malabar long before the place of their growth was known. 50,000 have last year been planted by an enterprising Frenchman; and there is little doubt that, if labour was more abundant, and means of communication were constructed, the Seychelles might be made a valuable dependency to the Mauritius. Tortoise-shell is exported from these islands. A gale of wind is unknown in these tranquil seas; but the ocean breezes are constant, thus tempering the rays of a vertical sun. Diego Garcia is situated about four degrees further E., and is one of those numerous coral islands with which these seas abound. It contains abundance of turtle; and has a few residents from the Mauritius. (H. B. J.)

MAURO, Fra, the most celebrated cosmographer of his time, was a friar of the Order of Camaldoles, in the monastery of St Michele di Murano, near Venice. He flourished in the fifteenth century; but the date of his birth and death are alike unknown. The fame he had acquired in the physical and mathematical sciences caused him to be chosen, in 1444, member of a commission of fifteen Venetian patricians, who were intrusted by government to regulate the course of the River Brenta, and to direct the work relating to the lagunes. Between 1457 and 1459 he made his celebrated map of the world, which has been so frequently copied, and which may still be seen in his monastery near Venice. In that singular production the progress of geographical science is marked with the utmost precision. In addition to the travels of Marco Polo, Fra Mauro marked down Cape Verde, Cape Roxo, the Gulf of Guinea, and all he could learn from the navigators of that day, who have left no written account of their voyages. Thus, Darfur, unknown to Europe till the time of Bruce, is mentioned under the name of *Dafur.* He also took notice of what was known to the Arabs, who at that time had pushed their discoveries on the coast of Africa as far as Sofala, and even visited Madagascar.

The highest glory of Fra Mauro, however, was the efficient aid he rendered to the two greatest expeditions of modern times, which resulted in the discovery of the Cape of Good Hope and the continent of America. His map is the first in which the E. and W. coasts of Africa are made to approach each other till they almost form a point, clearly indicating the passage round the Cape. There also may be seen beyond the Azores (faintly indicated and erroneously marked, it is true) several islands named Antilles and Brazil; and it is precisely by these names that Columbus and Vespucci distinguished the land they first discovered; thus favouring the conclusion that it was on the faith of Fra Mauro's map of the world that they were incited to their bold and immortal discoveries. Alphonso V. of Portugal requested Fra Mauro to draw a planisphere to serve as a guide to the intrepid Portuguese mariners, who had already endeavoured to find a passage to the East Indies; and we gather from a writer of the time (Francis Alvarez), and from the account-book of the monastery of S. Michele, that a copy of the map still existing there was given to the captain of two caravels sent out on a voyage of discovery in 1487, and paid for by King Alphonso. The Venetian Republic ordered a medal to be struck, on which may be seen the likeness of Mauro surrounded by the inscription, "*Frater Maurus S. Michaelis Moranensis de Venetiis Ordinis Camaldonensis Cosmographus incomparabilis.*" The last and most complete account of the planisphere is that by the Cardinal Placido Zurla: *Il Mappamondo di Fra Mauro de critto ed illustrato*, Venezia, 1806. (E. F.)

MAUROLYCO, or **Maurolycus, Francis**, the greatest geometrician of his age, was born at Messina in September 1494. After he had completed the course of study requisite for entering the church, he resolved to devote the rest of his life to mathematics. His father is said to have been his only instructor in that science; yet in a short time Maurolyco was selected to teach geometry to the eldest son of the viceroy, John de Vega. At the court of that prince he formed a friendship with Cardinal Alexander Farnese, and the Marquis Geraci. The latter conferred upon him the rich abbey of Santa Maria del Parto, and employed him to teach mathematics in the college of Messina. Thither geometricians from all parts of Italy were wont to resort for the purpose of consulting Maurolyco. After the death of his patron Geraci, Maurolyco retired to the country. He died in July 1575. His principal works are,—An edition of the *Spherics* of Theodosius, folio, 1558; *Martyrologium*, 4to, 1566; *Opuscula Mathematica*, 4to, 1575; *Arithmeticorum libri duo*, 8vo, 1575; *Euclidis Phænomena*, 4to, 1591; *Emendatio et Restitutio Conicorum Appollonii Pergæi*, folio, 1654; and *Archimedis Monumenta Omnia*, folio, 1685. (For an account of his services to mathematics, see *Dissertation Fourth*.)

MAURY, Jean Siffrein, *Cardinal*, the son of a poor shoemaker, was born at Vauréas, in the department of Vaucluse, in 1746. After receiving his education at the seminaries of St Charles and St Garde in Avignon, he left his home at a very early age, and arrived in Paris a poor, friendless adventurer. A funeral oration on the Dauphin introduced him to the public in 1766, and its success led him to take orders, and to devote himself with ardour to the study of pulpit eloquence. Thus obtaining a fair scope, his oratorical powers raised him in quick succession to several appointments. For a eulogy on Fenelon, written in 1770, he was appointed vicar-general of the Bishop of Lombez; a panegyric on St Louis, pronounced before the French Academy in 1772, gained for him the appointment to the abbey of Frenade; and on account of a eulogy on St Augustine, delivered before the assembled clergy in 1775, he was nominated preacher to the court. He now became intimate with men of rank and genius, and, through their influence, was elected a member of the French Academy in 1785. In the following year the valuable priory of Lihons was bequeathed to him by his friend the Abbé de Boismont. During the troublous days of 1789 Maury's ardent temperament could not brook inactivity. Accordingly, he appeared in the assembly of the states-general as deputy of the clergy of the bailiwick of Péronne. At first he was content to be a silent spectator of the confused wranglings of his associates. In the month of September, however, when the *veto* of the king came to be discussed, Maury threw aside his taciturnity, and stood forth as a bold defendant of monarchy. Recognised in a short time as one of the champions of the aristocratic party, he often entered the lists against Mirabeau, and his cool courage and ready eloquence made him almost a match for that redoubtable orator. He showed the same self-possessed heroism in the troubled streets of Paris; and never moved abroad without two loaded pistols. On the 9th of November 1789 he threw the Assembly into violent commotion by his bold and persistent opposition to the conversion of church property into national domains. Coming out of the hall on the same day among the infuriated mob, he was received with a universal shout, "To the lamp-iron with Abbé Maury!" "Well," replied the imperturbable abbé, "here he is; when you hang him on the lamp-iron, will you see better there?" and by this ready joke he threw the multitude into convulsions of laughter, and saved his own life. At the dissolution of the Assembly in 1792 he left France. His fame had gone before him; and after meeting the most hearty welcome at Chambery, Brussels, Lièges, and Coblentz, he was summoned to Rome by Pius VI. He was received with great distinction; was nominated archbishop of Nicæa *in partibus*; and was despatched as papal nuncio to the diet assembled at Frankfort for the coronation of Francis II. In 1794 he was appointed cardinal, and bishop of the united see of Montefiascone and Corneto. The terrors, however, which had driven him from his native country followed him to his place of refuge. The armies of republican France entered Rome in 1798, and Cardinal Maury was obliged to skulk for some time in Tuscany, and afterwards to flee to Venice under the guise of a carrier. He then retired to Russia, but returned to Rome in 1799 in the suite of Louis XVIII. After this period, a growing desire to visit Paris, the scene of his early greatness, seems to have gradually extinguished his zeal for the Bourbons. Accordingly, he followed the example of the Holy See by recognising in 1804 the government of Napoleon. In 1806 he returned to the French capital by permission, but found that his political apostacy had excluded him from those brilliant circles in which he was wont to move. Warmly befriended, however, by Bonaparte, Maury was nominated a French cardinal, and appointed chaplain to King Jerome. His elevation to the archbishopric of Paris followed in 1810, and subjected him to the heavy displeasure of Pope Pius VII.; but Maury silently refused to quit his see at the sovereign pontiff's command, and continued to show for his new master a devotion that verged upon slavishness. At the restoration of 1814 he was ordered to evacuate his archiepiscopal chair. Slowly and unwillingly he bent his steps toward Rome, and on his arrival in that city he was thrown into the castle of St Angelo. His liberation was purchased, after the lapse of a year, by his resignation of the see of Montefiascone and by other humiliations. He lived in retirement till his death in May 1817. Maury's principal work, *Essais sur l'Eloquence de la Chaire*, was translated into English by John Neale Lake, 8vo, London, 1793. After its author's death it was reprinted in the original by Louis Siffrein Maury, nephew of the abbé. The same editor published Maury's select works, with a Life, in 5 vols. 8vo, Paris, 1827.

MAUSOLEUM, a term applied in modern times to any sepulchral edifice erected for the reception of a monument, but which originally signified the sepulchre of Mausolus, a magnificent structure erected to the King of Caria by his queen Artemesia, at Halicarnassus, B.C. 353. The most eminent architects and artists of the time, of the Ionian and Attic schools, were employed by this pious queen to raise this splendid monument to the memory of her deceased husband, the dynast of Caria. Phileus and Satyrus were intrusted with the architecture; while the great Attic artists, Scopas, Bryaxis, Leochares, and Timotheus or Praxiteles, were employed on the sculptural decorations. These sculptors worked each at a face of the building, emulous of each other, and passionately devoted to their splendid undertaking. The queen died, but the artists continued their labours, and did not withdraw their hands until they had rendered it one of the seven wonders of the world.

Pliny's description of this structure (*Hist. Nat.* xxxvi. 5), though the most complete which we possess, is nevertheless in many respects unsatisfactory. This writer informs us that the building was an oblong quadrangular *cella*, 63 feet from N. to S., 411 feet in circumference, and 37½ feet in height; decorated with a peristyle of 36 columns, and carried up into a pyramid, surmounted at the apex by a marble quadriga, executed by Phileus, one of the architects. The entire edifice has a total height, from base to summit, of 140 feet. The discrepancy between the total and the partial heights can only be got over on the assumption that the peristyle was elevated on a basement; and the apparent discrepancy between the lengths of the faces and the total circuit, can only be explained by supposing that the structure stood upon an elevated inclosure, with a perimeter of 440 feet, the length given by the Bamberg MS. Direct measurement of it is impossible, for unfortunately this magnificent edifice no longer exists; the very site of it is doubtful, and the only remnant of its former splendour is to be found in the *Budrum Marbles* in the British Museum. These precious fragments of the handiwork of those devoted artists were collected in 1846 around the walls of *Budrum*, now occupying the site of the ancient Halicarnassus. Many of the slabs and columns of the Mausoleum were, in the fifteenth century, worked into the fortifications of this modern city; yet recent travellers cherish the hope that, from the materials still in existence, the plan of this famous sepulchral edifice may yet be restored. (For an examination of the proposed restoration, see a very able essay, with illustrations, *On the Sculptures from the Mausoleum at Halicarnassus*, by Charles Newton, in the Classical Museum for July 1847.)

The Roman mausolea were for the most part built in a series of circular terraces, after the manner of the *rogus*. Those of Augustus and Hadrian were the most celebrated; the latter of which has been converted into the Castello di St Angelo, the fortress of modern Rome, while the former has been reduced almost to a heap of ruins.

MAXENTIUS, Marcus Aurelius Valerius, a Roman emperor, was raised to the throne A.D. 306, and was defeated by Constantine and drowned in the Tiber A.D. 312. (See Roman History.)

MAXIMIANUS, Galerius Valerius, a Roman emperor, was the son of a shepherd in Dacia, was raised to the throne along with Constantius, A.D. 305, and was cut off by a loathsome disease A.D. 311. (See Roman History.)

Maximianus, *Marcus Aurelius Valerius*, a Roman emperor, was born in Pannonia of poor parents, divided the empire with Diocletian A.D. 286, abdicated the throne A.D. 305, was restored by his son Maxentius A.D. 306, and strangled himself A.D. 310. (See Roman History.)

MAXIMINUS, Caius Julius Verus, a Roman emperor, was originally a Thracian shepherd, was invested with the purple by the mutinous soldiers A.D. 235, and was murdered by his insurgent army A.D. 238. (See Roman History.)

Maximinus, *Galerius Valerius*, a Roman emperor, was originally an Illyrian shepherd, shared the empire with Licinius A.D. 311, and died A.D. 314. (See Roman History.)

MAXIMUS, the Confessor or Monk, a famous ecclesiastic, was born of noble parentage at Constantinople, about A.D. 580. He was educated with great care, and was early distinguished both for talents and piety. After he had attained his prime, he was reluctantly withdrawn from his favourite study of philosophy to become secretary to the Emperor Heraclius. It is also said that his royal patron wished him to write the civil history of that age. But when the emperor, about the middle of his reign, aimed at re-admitting the Monothelites within the church, Maximus boldly protested against such sinful policy by forthwith vacating his situation. This decisive step was probably accelerated by a lingering desire for the life of a recluse; for he immediately crossed to Asia, and entered a monastery at Chrysopolis (*Scutari* or *Iskudar*). There his extreme asceticism speedily raised him to the rank of abbot. At a later date Maximus, now well advanced in years, is found in the Roman province of Africa, arguing face to face with the Monothelites, writing letters and tracts to refute them, and summoning to his aid, in this determined warfare, all available power, both civil and ecclesiastic. He then, in 649, bent his steps towards Rome to fan the orthodox zeal of the new pope, Martin I. But Maximus, as the head of the Dyothelitic party in the church, and therefore the chief opposer of the imperial decrees in favour of Monothelitism, had become obnoxious to the Emperor Constans II. He was accordingly apprehended in 653, carried to Constantinople, and thrown into prison. On the day of trial the far-famed piety of the aged abbot secured the respect of his judges. He was merely asked to sign a formulary which had been drawn up for the occasion, and which might have been shown, by an ingenious interpretation, to include his doctrinal tenets. But Maximus refused to conceal the very smallest of his honest convictions under the guise of ambiguous expression. Persuasions, threats, and flatteries were all tried in vain; and he was therefore sentenced to imprisonment in the castle of Bizya (*Viza*) in Thrace. There the most cruel and most ignominious treatment could not alter his opinions, and at last his constancy outlived the patience of his enemies. In 662 he was dragged again to Constantinople, where, after being publicly scourged, he had his right hand chopped off and his tongue cut out. The old man was then banished to the Caucasus to die of his manifold sufferings.

The writings of Maximus display acute and profound thought, expressed in language often obscure and inelegant. A collection of his works, published by Combéfis in 2 vols. folio, Paris 1675, consists of letters, answers to theological questions, controversial tracts, and moral and monastic pieces. (For a list of his numerous productions, see Smith's *Dictionary of Greek and Roman Biography*.)

Maximus, *Magnus Clemens*, a Roman emperor, was a native of Spain, was invested with the purple A.D. 383, and was beheaded by Theodosius A.D. 388. (See Roman History.)

Maximus, *Petronius*, a Roman emperor, descended from the nobility of Rome, was born about A.D. 388, was proclaimed emperor A.D. 455, and was assassinated in the same year. (See Roman History.)

Maximus, *Tyrannus*, a Roman emperor, was raised to the supreme power by Gerontius A.D. 408, was forced to abdicate by Constantine A.D. 411, and was put to death A.D. 422. (See Roman History.)

MAXWELLTOWN, a borough of barony in Scotland, county of Kirkcudbright, is situated on the Nith, opposite Dumfries, with which it is connected by two bridges, and of which it was formerly a suburb, known by the name of Bridgend. It contains a church, several schools, a town-house, and several iron-works, rope-works, mills, &c. The borough is governed by a provost and two baillies. Pop. (1851) 3820.

MAY, the fifth month of our modern year, was the third of the old Roman calendar. The name is of doubtful origin. Ovid (*Fasti*, v. 483–90) suggests the three derivations of *majestas*, *majores* (the *patres* of the old Roman city), and *Maia*, the mother of Mercury, to whom the Romans were accustomed to sacrifice on the first day of the month. Others, again, have been of opinion that its origin is Teutonic, being derived from some obsolete word signifying youthful beauty and loveliness. The Saxons, after the Romans, called it *Maius monath*. It was considered unlucky among the Romans to contract marriages during this month, on account of the celebration of the Lemuria,—a superstition of which traces are still to be found among ourselves.

MAY-DAY, the name given to the first of the month in this country, when, according to ancient custom, all ranks of the people rose at early dawn and went out *a-Maying* to welcome the first return of the spring. The rites and festivities peculiar to this occasion can be traced back, according to some, to the heathen observances with which the Latin goddess Flora was wont to be honoured. At all events, some of the English ceremonies of May-day are as old as the Druids, who were accustomed to light large fires on the heights on May-eve, to herald with devout joy the coming spring. In the time of Bourne (*Vulg. Antiq.*) the juvenile part of both sexes in the villages of the north of England were wont to rise shortly after midnight on May morning, for according to Chaucer, "May wole have no sloggardye a night," and proceed, accompanied by music and horn-blowing, to some neighbouring wood, where, after breaking down branches from the trees, and adorning themselves with nosegays and garlands, they returned home at sunrise and decorated their doors and windows with the flowery spoil. Nor was this custom limited to the vulgar: even royalty itself occasionally condescended to share in this diversion. Chaucer, in addition to his beautiful allusion to the May-day customs in the *Knightes Tale*, says in his *Court of Love*, that early on May morning—

> "Fourth goeth al the court, both moste and leste,
> To feche the floures freshe, and braunch and blome."

And Hall, in his *Chronicle*, gives an account of Henry VIII.'s riding a-Maying with Queen Katherine from Greenwich to the high ground of Shooter's Hill, accompanied by many lords and ladies, who "went with their bows and arrows shooting to the wood." Shakspeare alludes also to the custom when he says, in his *Henry VIII.* (act v., scene 3), that it was impossible to make the people sleep on May morning; and when, in his *Midsummer Night's Dream* (act iv., scene 1), he talks of doing "observance for a morn of May." May-dew was also believed to possess a singular virtue. Samuel Pepys, in his *Diary*, informs us that his wife had gone down to Woolwich "to take a little ayre and gather May dew," in consequence of being told by a certain lady that "May-dew was the only thing in the world to wash her face with." Other minor observances on May-day were those of dancing round the May-pole decked with garlands, still known in England; the Jack-in-the-Green of the chimney-sweepers, who still perambulate and dance in the streets of London (see the *Times* of May 2, 1844; also *Literary Gazette*, May 1847); and the custom, now half a century old, of the London milkmaids, adorned with a garland of plate (hired for the occasion), and a profusion of flowers, dancing before the doors of their customers to the music of a fiddle. Old Stow, in his *Survay of London* (1603) sums up a number of the festive details of May-day in the following sentence:—"I find also that, in the moneth of May, the citizens of London, of al estates, lightly in every parish, or sometimes two or three parishes joyning togither, had their severall Mayings, and did fetch in May-poles, with diverse warlike shewes, with good archers, morice-dancers, and other devices, for pastime al the day long, and towards the evening they had stage-players, and bone-fiers in the streetes." These May customs were not, however, wholly limited to England. (But for further information, see Brand's *Popular Antiquities*, vol. i., p. 212; also Grimm's *Deutsche Mythologie*, p. 448, &c.)

MAY, ISLE OF, a small island of Scotland, county of Fife, in the Firth of Forth, 6 miles S.E. of Crail. It is about a mile in length, and nearly a mile in breadth, consisting of slaty rock. It affords pasturage for sheep and cattle, and is frequented by great numbers of sea-birds. There is a lighthouse on the island with a fine dioptric light, 240 feet high, and visible from a distance of 21 miles. The cliffs are for the most part steep and perpendicular, rising in some places to the height of 160 feet. Pop. (1851) 18.

MAY, THOMAS, an English historian and poet, was born in 1595 of an ancient family in Sussex. He was educated at Cambridge, and, after taking the degree of B.A., he repaired to London, and became a member of Gray's Inn. In the course of time his talents found favour at court, and several of his poems were published by the special command of Charles I. He was thus led to expect the laurel on the death of Ben Jonson in 1637. But Sir William Davenant was preferred; and May abandoned the court in a pet, and was ever afterwards a republican. During the civil war he became secretary to the Parliament, and was employed to write its *History*. This work, published originally in Latin, was translated into English in 1650. It is tame and inelegant, yet, on the whole, it is truthful in its facts, and unbiassed in its judgments. On the night of the 12th of November 1650, May retired to bed in good health, "after his chearful bottle as usual," and died in his sleep before morning. His remains were laid in Westminster Abbey; but soon after the Restoration they were disinterred, and thrown into a pit in the adjoining churchyard of St Margaret's. A monument that had been erected over his grave was also demolished.

May is the author of five plays, and of two poems on the reigns of Henry II. and Edward III. respectively. He translated into English verse *Selected Epigrams of Martial*, Virgil's *Georgics*, and Lucan's *Pharsalia*. To the last of these he wrote a continuation both in English and Latin. His *History of the Parliament* was edited by Baron Masères, 4to, 1812.

MAYBOLE, a borough of barony, and market-town of Scotland, county of Ayr, is pleasantly situated on a hill 5 miles from the sea, and 9 S. of Ayr. The town is well built, especially the ancient part, owing to its having been formerly the residence of many of the aristocracy, as the capital of the district of Carrick. The town possesses several specimens of baronial residences, among which the most remarkable is the castle, which was formerly occupied by the Earls of Cassilis, and now by a factor of the Marquis of Ailsa. The parish church is a large but clumsy building; and there are also Free, United Presbyterian, and Wesleyan churches. Maybole has besides several schools, libraries, a savings-bank, and other institutions. The inhabitants are employed to a considerable extent in handloom weaving. West of the town stand the ruins of Crossraguel Abbey, one of the abbots of which, Quintin Kennedy, held a disputation with John Knox in Maybole in 1561. This discussion lasted for three days, and ended unsatisfactorily, both disputants claiming the victory. The house where the disputation took place is now the Red Lion Inn. Pop. (1851) 3862.

MAYEN, a walled town in Rhenish Prussia, capital of a circle of the same name, in the government of Coblentz, is situated on the Nette, 17 miles W. of Coblentz. It has manufactures of woollen cloth, paper, and earthenware. Pop. 5288.

MAYENCE (German *Mainz*, ancient *Moguntiacum*), a town of Germany, capital of the province of Rhenish Hesse, in the grand duchy of Hesse-Darmstadt, is beautifully situated on a sloping hill on the left bank of the Rhine, not far from its confluence with the Main, 20 miles W.S.W. of Frankfort. The town is built in an irregular and old-fashioned style; most of the streets are narrow and gloomy, the houses are in general high, and the squares have a fine and imposing appearance. Outside the town there are large public gardens, called Neue Anlage, which form a fashionable and much frequented promenade, and command a fine view of the town and surrounding country. The cathedral, which is of great antiquity, and has been destroyed by fire not less than six times, exhibits specimens of the styles of several centuries; and, though interesting as an illustration of the history of art, it does not possess much architectural beauty, and is not seen to advantage, owing to its being blocked up with mean houses. It has six towers, one of which is above 200 feet in height, while another, of 70 feet, is surmounted by a cupola. The building contains many monuments of much interest and of great antiquity; a handsome pulpit, 14 altars, and 20 chapels. There is also the church of St Ignatius, built in a beautiful style, and adorned with fine pictures by Zick. The other important buildings in Mayence are,—the church of St Peter, with two towers and a fine peal of bells; that of St Stephen, whose tower commands a fine view; the ancient palace of the electors, now used as the merchants' hall; the grand ducal palace, now occupied by the governor, and formerly the palace of the Teutonic order; the library, containing 100,000 volumes; and the theatre. There was formerly a college here; but its place is now supplied by a gymnasium. Opposite the theatre stands a bronze statue by Thorwaldsen of Gutenberg, a native of this town, who is one of the claimants of the honour of the invention of printing, as he was the first to use metal types. In the citadel stands the Eichelstein, supposed to be the monument mentioned by ancient authors as erected here in memory of Drusus, brother of the emperor Tiberius, and father of Germanicus. The town of Mayence is strongly fortified, and is indeed one of the strongest places in Europe, serving as a defence for Germany on the side of France. On the other side of the Rhine stands the suburb of Castel, which is joined to the town by a bridge of boats, and also fortified; and a small island in the river, called Petersan, is no less securely defended. Mayence has towards the country 4 gates, with double drawbridges, while the whole extent of the defences is so great as to require a garrison of 30,000 men to man them fully. The fortress belongs to the German Confederation; and is garrisoned in time of peace by 6000 Austrians, Prussians, and Hessians, under an Austrian and a Prussian general alternately, each of whom retains the command for five years. There is believed to have been a town of the Mediomatrici on the site of the modern Mayence, before the foundation of a fortress here by Drusus, in the year 13 B.C. The town does not, however, seem to have been of any great importance during the continuance of the Roman empire; and was destroyed by the Vandals in 406. After lying in ruins for some centuries, Mayence was restored by Charlemagne, and attained to great prosperity after the time of Bonifacius, bishop of Mayence. In the middle ages this was the first ecclesiastical city of Germany; and the archbishop was one of the electors, and premier prince of the German empire. In 1798 Mayence having fallen into the hands of the French, was made the capital of the department of Mont Tonnère; but in 1816 it was given to the Grand Duke of Hesse. Pop. 31,365.

MAYENNE, a department of France, bounded on the N. by those of Manche and Orne, E. by that of Sarthe, S. by those of Maine-et-Loire and Loire Inferieure, and W. by that of Ille-et-Vilaine. It is 55 miles in length by about 30 in breadth. The department is bounded by low ranges of hills on the N., E., and W., and has a general slope towards the S. It consists of gently undulating plains without any marked elevation or depression. The principal river, the Mayenne, from which it derives its name, traverses it from N. to S., dividing it into two nearly equal parts. The department contains also several small lakes. The rocks of Mayenne belong almost entirely to the earliest geological epochs, and contain a considerable amount of mineral resources. Iron, coal, limestone, marble, slate, granite, building-stone, &c. are obtained in the department. The soil is not very fertile, except in the southern parts, where all sorts of corn are grown, while in the other districts the produce of the soil is not sufficient to supply the wants of the inhabitants. Of the entire area of the department, 885,000 acres are occupied with arable land, 172,500 are meadow land, and 65,000 wood. Notwithstanding the small extent of the meadow-land, a great number of live stock is reared on the heaths and fallow land of the department; and the cattle are of good breed, and highly prized. It has been calculated that there are in Mayenne 50,000 horses, 180,000 head of large cattle, 140,000 sheep, 50,000 pigs, &c. The department is very much broken up into small farms, some of them so small as to be cultivated with the spade; and the population live in their own separate farm-houses, instead of congregating in towns and villages. The effect of this on the character of the people may be seen in the blunt honesty and obstinate independence by which the peasant of Mayenne is characterized; but they are also both unable and unwilling to engage in any enterprize for improving their ground, by which their condition might be bettered. The fields are in general surrounded by hedges and rows of trees; and this gives the country, when seen from a distance, the aspect of a vast forest. The principal manufacture carried on in the department is that of cloth, especially table linen and sailcloth; and there are also several forges and iron-works. The trade consists principally in iron. Mayenne contains several ancient Roman and Druidical remains; and at Jublains there have been preserved the remains of one of the strongest Roman forts to be seen in France. In the middle ages this department was the scene of many bloody encounters between the English and the French; and in the Vendean war a great victory was gained here by the Royalists under Larochejacquelin, in 1793, over the Republican forces. The capital of the department is Laval; and it is divided into three arrondissements as follows:—

	Cantons.	Communes.	Population.
Laval	9	92	130,523
Château-Gonthier	6	72	78,862
Mayenne	12	110	165,181
Total	27	274	374,566

MAYENNE, a town of France, capital of the arrondissement of the same name, in the above department, is irregularly built on both sides of the River Mayenne, 18 miles N. by E. from Laval. The streets are extremely steep, and the houses quaint and old-fashioned. The principal building is the old castle on the right bank of the river. Mayenne has some manufactures, especially of linen fabrics; and there are also cotton mills, bleachfields, and dye-works. The trade consists in the productions of its manufacture and agriculture, especially grain and cattle. The town was formerly strongly fortified, and resisted for three months a siege by the English, under the Earl of Salisbury, to whom it surrendered in 1424. In 1544 it was made a duchy by Charles IX., and gave the title of Duke of Mayenne to

Charles of Lorraine, afterwards famous as the head of the League. Pop. (1851) 9588.

Mayenne (anciently *Meduana*), a river of France, rises in the hills of the department of Orne, near Pré-en-Pail, and flows westward till its confluence with the Varenne. It then takes a southerly direction, and empties itself into the Loire. In the upper part of its course it is inclosed between rocky banks; but from Laval, where it becomes navigable, it flows southward with a broad and deep current through extensive and beautiful meadow-lands. The principal towns on its banks are Mayenne, Laval, Entrames, and Château-Gonthier. It receives, from the right, the Ernée and the Oudon, and from the left the Aron and the Jouanne. Its total length is 125 miles, and it is navigable for 55 miles.

MAYER, Tobias, one of the greatest astronomers of the eighteenth century, was the son of a civil engineer, and was born at Marbach in Würtemberg, on the 17th February 1723. The elements of mathematics he received from his father, but the rest of his knowledge in that science was self-acquired. At an early age he was left an orphan, and was forced to earn a livelihood by giving mathematical lessons. His first publications, *A Treatise on Curves for the Construction of Geometrical Problems*, and *A Mathematical Atlas*, appeared in 1745. In the following year he contributed to the establishment of the Cosmographical Society of Nuremberg. He was appointed director of the observatory of Göttingen in 1751; and there, in the midst of the turmoil of the Seven Years' War, and in the vicinity of powder magazines, he prosecuted his studies with untiring devotion. The *Lunar Tables*, the chief result of his labour, appeared in the "Acts of the Academy of Göttingen" in 1755. About this time also, Mayer discovered the principle of the *Repeating Circle.* His extreme application, however, had caused a disease which was gradually undermining his health. He died on the 20th February 1762, at the age of thirty-nine. Over his grave at Göttingen, a monument was erected in 1801. (For an account of Mayer's Lunar Tables, and his invention of the Repeating Circle, see *Dissertation Fifth*, § 2, pp. 749, 781.)

An edition of his works had been promised, but of these only one volume appeared under the care of Lichtenberg, his friend and associate. It contains, 1. A method for determining more exactly the variations of the thermometer, with a formula for calculating the mean degree of heat in every latitude, and the seasons of the year in which occur the greatest heat and the greatest cold. 2. A memoir on the observations which he made with his mural arc of six feet, and the verifications to which he subjected that instrument. 3. An easy method for calculating eclipses of the sun, being at bottom the method of Kepler, which Lacaille also reproduced in his *Leçons d'Astronomie.* 4. A memoir on the affinity of the colours, in which he recognised only three primary colours, all the rest being obtained by different combinations of these. 5. His new catalogue of the stars, the work of two years, during which he experienced several interruptions, especially when the old tower on which his observatory stood was converted by the French into a powder magazine. 6. A memoir, followed by a catalogue of eighty stars, to which he assigned a peculiar motion, independently of the general motion of precession. His éloge, pronounced at the academy by Kaestner (Göttingen, 1762, in 4to), is followed by a list of his works, which we shall here subjoin. 1. Description of a new Globe of the Moon; 2. Terrestrial Refractions; 3. Geographical Charts, including a Critical Chart of Germany, and a Map of Switzerland; 4. Description of a new Micrometer; 5. Observations on the Eclipse of the Sun in 1748; 6. Conjunctions of the Moon and the Stars observed in 1747 and 1748; 7. Proofs that the Moon has no atmosphere; 8. Motion of the Earth explained by a change in the direction of gravity; 9. Latitude of Nuremberg, and other Astronomical Observations; 10. Memoir on the Parallax of the Moon and its distance from the Earth, deduced from the length of a pendulum beating seconds; 11. On the Transmutation of rectilineal figures into triangles; 12. Invention of a species of Painting of which the products may be multiplied; 13. Inclinations and Declinations of the Magnetic Needle, deduced from theory; 14. Inequalities of Jupiter.

MAYNOOTH, a town of Ireland, in the province of Leinster, and county of Kildare, is situated on the Royal Canal and Rye Water, 15 miles W. by N. of Dublin. The town consists of one street, extending from the entrance to Carston, the seat of the Duke of Leinster, on the E., to the Roman Catholic college on the W. There are in Maynooth a parish church, a Roman Catholic chapel and nunnery, a court-house, schools, and a dispensary. The college of Maynooth is a plain brick building, in the form of a quadrangle, with a frontage of 400 feet in length. The grounds belonging to it occupy an area of 54 acres. (For further particulars respecting this institution, see Ireland.) Near the college stand the ruins of Maynooth Castle, built in 1426, and formerly the residence of the Fitzgerald family. Pop. (1851) 2201.

MAYO, a maritime county in the province of Connaught in Ireland, is bounded on the N. and W. by the Atlantic Ocean, on the E. by the counties of Sligo and Roscommon, and on the S. by that of Galway. According to the Ordnance Survey, it comprises an area of 2131 square miles, or 1,363,882 acres; of which 497,587 only are arable, 800,111 uncultivated, 8360 in plantation, 848 in towns, and 56,976 are under water. Although this county contains a greater extent of unimproved waste lands than any other in Ireland, a large portion, more particularly in the baronies of Erris and Burrishoole on the western coast, present great facilities for reclamation and cultivation. Of the great extent of bog and moor land situated in the barony of Tyrawley, W. of Ballina, much might be improved for cultivation; but owing to the scarcity of manure, so easily obtainable on the coast of Erris and Burrishoole, not with equal advantage as in those baronies. Of the entire 800,000 acres of uncultivated land, it is estimated that 170,000 might be improved for cultivation, 300,000 might be drained for pasture, and about 330,000 must be considered unimprovable.

According to Ptolemy, the earliest inhabitants of this region were the Nagnatæ. It was afterwards divided into districts, distinguished by the names of the chieftains or principal settlers; of whom those of greatest note were M'William Oughter, O'Maley, M'Jordan, O'Dondey, and O'M'Philben, to which were subsequently added the Nangles, the Dillons, and others of British descent.

The whole of Connaught, except Roscommon, was considered as one county by the English, until the beginning of the reign of Elizabeth, by whom it was made shire ground, and this county then took its name from the monastery of Mayo or Mageo in it. It is now divided into the nine baronies of Burrishoole, Carra, Clanmorris, Costello, Erris, Gallen, Kilmaine, Murrisk, and Tyrawley. The county is in the dioceses of Tuam, Killala, and Achonry.

The appearance of the country varies very much. In the eastern parts it contains extensive plains capable of cultivation, and rising occasionally into hills of moderate height; the western part is wholly mountainous, and covered in most parts with bog, except in some places near the sea, where the soil, unless when covered with drifted sand, is sufficiently fertile. In some parts of the flat country, near Lough Mask, the ground appears like one plain of greystone, which, on a closer examination, is found to consist of parallel layers of rock rising edgeways out of the ground, and having the intervening furrows filled with a productive soil that throws up an herbage peculiarly grateful to sheep. Among the principal mountains, Muilrea (2688 feet high, the most elevated point in Connaught), is conspicuous. This fine mountain, which, with Bengorm (2286 feet), forms the northern or Mayo side of Killary Harbour, has its summit level about a mile from the sea, towards which it presents a grand and imposing aspect. Croagh-Patrick (2530 feet high) stands on the southern shore of Clew Bay. This mountain is amongst the most celebrated in Ireland, not only for its height and the majestic outline it presents from the various positions whence it can be viewed, but from the tradition that St Patrick chose its summit as the place to stand on when he drove all the venomous reptiles of the island into the sea. Nephin, 2640 feet high, to the W. of Lough Conn, is of a conical form, with rugged and steep sides, quite isolated by its great elevation over the neighbouring country, and covered with Alpine plants to its summit. Nephin-beg, in its vicinity, is 2065 feet high. In the same district is the mountain of Berreencurragh, 2290 feet high; and more westward, Maam-Thomoish and Croughletta, each very lofty, though less elevated than the preceding. The rivers which flow from these mountains are small, unless when their body of waters is increased by a violent fall of rain. The principal are the Aull, which is navigable for large boats for 5 miles from Lough Mask; the Castlebar (or Clydagh) River, in like manner, navigable for 4 miles from Lough Conn; the Owenmore, an excellent salmon river, which flows through Erris, and falls into Blacksod Bay; the Deel, the Robe, the Errive, and the Carnamart. The splendid River Moy, which separates this county from Sligo, is navigable to within a mile of Ballina for vessels of 450 tons, and as a salmon river ranks second only to the Bann. The Black River, which is the boundary on the S., is remarkable for having an underground course of some miles near its embouchure into Lough Corrib. Amongst the numerous lakes, Lough Mask, situated in the S., and separated from Lough Corrib by a narrow isthmus, is the largest. It is 10 miles long by 4 broad, but its southern extremity is included in Galway county. Lough Carra, to the N.E. of Lough Mask, is a picturesque sheet of water, but much inferior in this respect to the beautiful Lough Raheens, called also Castlebar Lough from the town in its vicinity; and Lough Conn, still farther N., is a fine sheet of water 12 miles long, including Lough Cullin, but of very inconsiderable breadth. The minor lakes are numerous, and there are several turloughs, in which the water collects in winter, but is carried off by a natural drainage at the beginning of summer.

The western and northern coasts are indented with numerous bays and creeks. Killary Bay, or the Killary, which separates Mayo from Galway, is a narrow inlet of the sea, reaching 8 miles from the Atlantic, and only about half a mile in breadth, bounded on both sides throughout its entire length by mountains which, on the Mayo side, rise to nearly 3000 feet in height, and resembling the scenery of a Norwegian fiord. Proceeding northwards, the next inlet in order, and the most worthy of note for extent and grandeur of scenery, is Clew Bay, protected at its entrance by Clare Island, and having in its interior the two harbours of Newport and Westport, besides many creeks and roadsteads caused by the almost innumerable islets with which its eastern coast is studded. Blacksod Bay and Broadhaven form the peninsula of the Mullet, and are prevented from blending their waters only by the very narrow isthmus of Bellmullet. On the northern coast are Dunfinney and Killala Bays. The lesser indentations of the coast, affording shelter for small craft, and therefore of much importance to the fisheries, are too numerous to admit of specific detail.

The principal island is that of Achill. It is the largest on the Irish coast, containing 35,283 acres, and about 3500 inhabitants, and is formed partly of lofty hills and partly of flat bogs. The western side presents a rugged and precipitous line of rock to resist the violence of the Atlantic, interrupted only by a few small coves, scarcely capable of sheltering the smallest boats; the eastern coast affords shelter almost everywhere. The highest mountain on the island, Slievemore, situated to the W. of the Protestant missionary settlement, is 2204 feet above the sea; and other summits attain elevations of 2192, 1800, and 1120 feet. Clare Island is of a triangular form, 3959 acres in extent, and has about 1400 inhabitants. Innisbofin, the most important island on the coast as respects the fisheries, is about 4 miles from Connemara in Galway; it had a garrison in the time of the republic. The finest cod-bank on the Irish coast lies near it. Innisturk lies midway between the two last-named islands. The want of a landing-place renders it nearly useless, notwithstanding its advantageous position for fishing. It comprehends 1450 acres of poor soil and rock. The lesser islands are scarcely of sufficient consequence to deserve enumeration.

The returns of the population of the county, taken at different periods, present the following results:—

Year.	Authority.	Population.
1760	De Burgo	77,508
1792	Beaufort	140,000
1812	Parliamentary return	261,821
1821	Ditto	293,112
1831	Ditto	366,328
1841	Ditto	388,887
1851	Ditto	274,612

The latest of these returns shows a decrease of population in 10 years of 114,275, or 29 per cent. As far as may be conjectured from the relative numbers of Protestant and Catholic children attending public schools in 1824–26, the proportion between the sects is upwards of 7 to 1 in favour of the latter persuasion.

The returns of the numbers educated are as follows:—

Year.	Boys.	Girls.	Sex not ascertained.	Total.
1821	6,150	3185	—	9,335
1824–6	10,827	5172	694	16,993

Of the numbers in the latter return, 1900 only were Protestants. In 1851 the number of schools, and of pupils attending them, during the week ending 12th of April, was found to be:—

SCHOOLS.	No. of Schools.	Number of Pupils.		
		Males.	Females.	Total.
National	119	2920	2400	5320
Church Education	26	462	444	906
Endowed	2	55	32	87
Boarding	2	15	15	30
Private	98	1734	992	2726
Parochial	7	152	136	288
Free	11	229	548	777
Industrial	6	17	234	251
Mission	59	860	1121	1981
Military	1	13	5	18
Workhouse	18	2075	2162	4237
Gaol	1	41	7	48
Total	350	8573	8096	16,669

The county was represented in the Irish Parliament by four members, two for the county at large, and two for the borough of Castlebar; but the two latter were struck off at the Union, and compensation, amounting to L.15,000, awarded to the Earl of Lucan, as proprietor of the borough, for the loss of the patronage. No alteration having been since made under the Reform Act, the number of representatives is now limited to two.

The number of resident landed proprietors is small in comparison with the extent of the county. The condition of the peasantry varies considerably according to their situation. On the sea-coast, where the occupation of fishing can be combined with that of agriculture, the people are tolerably comfortable. This is particularly the case in the district around Killala, Westport, Newport, and other places where an export trade is carried on; and early and improvident marriages are by no means so common in those parts. Similar appearances of comfort and prudence are observable in the inland eastern districts where agriculture is attended to. In the mountainous and boggy tracts the state of the peasantry is very deplorable. The houses are of the poorest description, and extremely confined in dimensions. But in the agricultural districts the case is different. In these the houses are of stone and mortar, with a chimney and separate apartments. The men dress in home-made frieze of a dark colour, and the women mostly in cheap cottons. The fuel is universally turf; the food potatoes, with milk occasionally, and when near the shore, fish. The Irish language is understood by 65 per cent. of the population, and about 50,000 persons are unable to speak the English language. In the inland and more retired parts the peasantry prefer collecting themselves in closely-built, irregular villages, to living in detached cottages. The custom of holding large tracts of land in joint tenancy, which is the favourite tenure in the pasturable regions, may be considered as the chief cause of this practice.

The soil in the plain country is chiefly a gravelly loam on a limestone bottom. Even in the tracts where bogs prevail, ridges of limestone gravel, called *eskers*, of a mile and more in length, several perches broad, and from 40 to 50 feet high, are to be met with. The rocky pastures produce a nutritive herbage for sheep and young cattle; and in places from which these are excluded, timber trees throw up their shoots spontaneously. Wheat is grown in large quantities in the southern and eastern baronies; oats, barley, and flax in the hilly country.

The extent of land under crops, and the number of acres under each species of crop in 1855 and 1856, was:—

	1855. Acres.	1856. Acres.
Wheat	4,638	6,086
Oats	83,543	84,249
Barley, bere, rye, pease, and beans	5,396	4,252
Potatoes	59,037	67,230
Turnips	9,556	10,604
Other green crops	2,193	2,227
Flax	745	923
Meadow and clover	18,229	16,964
Total	183,337	192,535

Where limestone can be had it is the favourite manure, either alone or in a compost with other substances. Where it cannot be procured, recourse is had to burning. Shelly sea-sand, and sea-weed thrown up by the high winds, are much used on the coast. The implements of agriculture are still of a clumsy and coarse make. The spade, called a *loy*, having a rest for the right foot only, is substituted for the plough in the mountainous parts. In Erris a spade with a blade forking out into two points is used where the soil is rocky. The fences are mostly dry-stone walls, formed by collecting the loose stones from the surface, where they are so abundant that the fences made of them present the appearance of ramparts rather than inclosures against trespassing.

The quantity of live stock in the county of Mayo in 1855 and 1856 was:—

	1855. No.	1856. No.
Horses	17,531	19,300
Cattle	153,583	157,856
Sheep	265,448	270,074
Pigs	38,348	33,372

Towards the close of the last century, planting, both for ornament in demesnes, and on a more extensive scale for profit, has been much attended to. The base of Croaghpatrick is finely fringed with wood, as is that of Nephin. The neighbourhood of Westport is much improved by extensive plantations. The baronies of Tyrawley, Burrishoole, Gallen, and Costello, however, are nearly destitute of timber.

The manufactures are almost wholly confined to articles in demand for home consumption, such as linens, furs, flannels, woollen stockings, and straw hats. The chief marts for the sale of the superabundant produce are Castlebar and Westport. Besides these legal sources of profit from manufactures, illicit distillation is still carried on to some extent. The exports are grain, fish, and kelp; large quantities of the latter are manufactured on the shores. Fishing banks are numerous. The principal one, between Innisbofin and Achill, affords an inexhaustible supply of white fish. Near Achill is a sandbank stocked with turbot and other flat fish, which are also taken in abundance off Killala Bay. Near Inniskea Island is a great ling bank. The sun-fish, or basking shark, is taken from 5 to 8 leagues from the coast. The fishery commences in the last week in April; but as the success of the season depends on the state of the weather, which is very liable to sudden and violent squalls at that season, and as the fish frequently escapes, bearing away with it the harpoon and tackle, the average profits, during a continuance of seasons, seldom compensate the adventurer for his outlay. The herring fishery occupies many hands. The whole fishing trade is carried on in open boats, as this description of craft is less expensive, and better adapted for the coasting trade in kelp and turf, in which it is employed during the intervals of the fishing seasons. The deep-sea fishing begins in May; that of the herring in August. The winter fishing continues from November to Christmas. Pollock, whiting, sand-eels, and shell-fish are caught along the shores, and there are salmon fisheries at Newport, Ballina, and other places.

The remains of ancient buildings are numerous, and many of them highly worthy of note. There are round or pillar towers at Killala, Turlough, Meeleek, and Bal; but the first, which stands on an eminence in the town, is the loftiest and best preserved. The Abbey of Mayo, which gives name to the county, was once the site of a bishop's see. Moyne Abbey, beautifully situated on the banks of the bay, near Killala, still exhibits some arches of magnificent size and excellent workmanship, with a tower rising not less than 100 feet from the top of the centre of the church. The ruins of Rosserick Abbey, in a sheltered dell near the estuary of the Moy, about 4 miles from Killala, are amongst the finest specimens of monastic buildings in the county. The workmanship of an arch in the centre of the church is peculiarly admirable. Although Ballyhaunis Abbey is much dilapidated, the remains of its ruins show it to have been, as it were, a miniature resemblance of that of Moyne. At Ballinrobe was the Abbey de Roba, of which no traces are now visible. Ballintobber Abbey, about 5 miles from Ballyglass, was founded by Cathal O'Conor, King of Connaught. The Abbey of Burrishoole, 2 miles distant from Newport, owes its origin to the Bourke family; its site is the place for holding a patron in honour of St Dominic. The remains of the church of Strade Abbey, on the Moy, still exist; they are singularly beautiful, and near the altar are several curious sculptures. Cross, or Holycross Monastery, was in the peninsula of the Mullet. The Abbey of Bophin was built in the island of Innisbofin. Many relics of other monastic buildings of inferior note are to be found in various parts. The remains of ancient castles and places of strength are also numerous. At Downpatrick, or Dunbriste, are the ruins of a strong castle on a cliff, 300 feet high, projecting into the sea. A rock of equal elevation rises at about the same distance from the shore, on which are also the traces of castellated buildings. The correspondence of the prominences and indentations of the rocks on each side of the cleft that separates these structures prove that they were once united. Rockfleet Castle, near Newport, is said to have been built by the celebrated Grace O'Mallay, to whom the erection of several other fortresses along the coast are attributed. This singular woman was so much attached to the sea, the scene of most of her exploits, that when on shore, she is said to have had her bark moored to her bed-post through a window of the castle where she slept. Ballylahan Castle, near Foxford, was built by one of the MacJordan family, who erected others of similar construction for each of his ten sons. Deel Castle, near Ballina, stands as yet; it was formerly the residence of the Earls of Arran, and is still inhabited. In Lough Conn are the ruins of a fort in which O'Conor, king of Ireland, is said to have confined his son. The smaller castles, or fortified houses, vestiges of which are visible in many parts, are almost invariably square buildings, with a narrow entrance and a few contracted windows, erected solely for security, without any regard to architectural beauty.

The towns in this extensive county are few and small, none of them having a population amounting to 5000. The principal are,—Castlebar, Westport, Ballina, and Ballinrobe, which will be found described under their respective heads. (H. S—R.)

MAYOMBA, or Mayumba, a seaport of Africa, in South Guinea, is situated at the mouth of the Mayomba River, 120 miles N.W. of Loango. It is the capital of a territory of the same name, which is governed by a chief dependent on the King of Loango. The harbour is convenient. The inhabitants, who are gentle and intelligent, find employment in working copper and procuring ivory and gum.

MAYOTTA, an island in the Mozambique Channel, the farthest S. of the Comoro group, is situated about 160 miles from Madagascar, in S. Lat. 12. 54., and E. Long. 45. 15. It is about 30 miles in length by 20 in breadth, and is for the most part of volcanic structure. It is mountainous, rising in some parts to the height of nearly 2000 feet; and many valleys and ravines occur, while the whole is covered by forests and luxuriant vegetation. The coast is indented with numerous bays, &c., and is surrounded by reefs, which render the landing difficult. The villages are two in number,—Choa, or Mayotta, the residence of the chief; and Zaondzi, on an island of the same name, which is included within the encircling reef. Mayotta has suffered much from the Madagascar pirates. It has been in the possession of the French since 1841. Pop. (1854) 6888.

MAYOW, or Mayo, John, a medical man of some eminence, but more remarkable for his curious speculations on some chemical subjects, was born in Cornwall in 1645. His most interesting work is a short Latin treatise, *De Sale Nitro, et Spiritu Nitro-äereo*, which appeared at Oxford in 1674. In this he adopted the theory of combustion of Dr Hooke, which had appeared about ten years before; and he added some ingenious original experiments, in which he appears to have anticipated some far more recent investigations on the weight gained by metals on calcination; and he maintained that atmospheric air underwent a change in composition during the combustion of fuel. The apparatus he employed in these experiments was ingenious, and not very different from that of modern chemistry. But the attention of chemists was drawn away from the simple explanations of Hooke and Mayow by the fanciful speculations of Stahl regarding *phlogiston*. In the 14th chapter of his little treatise we find that the ideas of Mayow on chemical *affinity* were much more accurate than those of any of his contemporaries; and we must regard him as one of the pioneers of modern chemistry, though some of his views are undoubtedly erroneous, as might be expected from the period in which he lived. He died at Bristol in 1679, at the early age of thirty-four. (T. S. T.)

MAYPU, a river of Chili, in the department of Santiago, rises in the Andes, between the volcano of the same name and the Peak of Tupungato, flows westward, and, after a course of 160 miles, falls into the Pacific. For about one-third of its course, the river flows in narrow ravines among the high mountain ridges of the Andes; but in the lower part of its course it traverses the S. portion of the plain of Santiago, which it waters by means of a canal. Its waters are much impregnated with salt, and dash along with an impetuosity which no ordinary bridge could withstand. It is therefore crossed only by swinging bridges of ropes, on the model of those of the ancient Peruvians. The Rio de Colina, from the plain of Santiago, falls into this river. In the plains traversed by the Maypu, a great and decisive victory was gained in 1818, by the republicans under San Martin, over the royalists, which put an end to the Spanish dominion in Chili.

MAYSVILLE, a town in the state of Kentucky, Mason county, North America, is situated on the S. bank of the Ohio, 60 miles above Cincinnati, and 73 miles N.E. of Frankfort. The town, which formerly went by the name of Limestone from a creek of that name, consists of a number of regular streets, crossing each other at right angles, and containing many well-built houses and shops. The principal buildings are,—a city-hall, a jail, an hospital, 7 or 8 churches, 12 schools and seminaries, and 2 banks. Manufactures of iron, cotton, ropes, &c., are carried on here. Maysville is a place of considerable trade, especially in the agricultural produce of the north-eastern districts of the state, and it has an excellent harbour on the Ohio. Pop. (1853) 6500.

MAZAMET, a town of France, department of Tarn, situated on the small River Larn, a tributary of the Agout, at the foot of the Black Mountains, 10 miles S.E. of Castres. It is within the last forty years that this town has acquired its present importance; for previously it was only an obscure village in a barren and thinly peopled country. The town has a Protestant consistorial church; and manufactures of coarse woollen stuffs, moleskins, cloth, paper, &c. Its trade is also considerable, comprising, besides its articles of manufacture, corn, wool, cattle, &c. Pop. 9894.

MAZANDERAUN, or Mazenderan, a province of Persia, bounded on the N. by the Caspian Sea, E. by Khorassan, S. by Irak-Ajemi, and W. by Ghilan, and lying between 36. and 37. N. Lat., and 50. and 54. E. Long. Length about 200 miles from E. to W.; average breadth 50 miles; area 10,000 square miles. The province is bounded on the S. by the high mountains of Elburz, which are covered with wood; but the most part of it consists of a low plain on the shores of the Caspian. Near the sea the country is very marshy; but at a short distance it takes a gradual ascent. None of the rivers are of great size, and all flow northward into the Caspian. The climate is not very healthy; but it is not so insalubrious as that of the adjoining province of Ghilan. The soil is good, and produces rice, cotton, mulberry, and sugar cane; as well as oranges, pomegranates, and other fruits. Cultivation is carried on to a considerable extent; the chief article raised being rice. Its trade, which is principally with Russia, consists in the exportation of rice, silk, and cotton; and the importation of woollen stuffs, corn, tobacco, cutlery, &c. The inhabitants resemble in appearance and costume the other Persians; but they have the reputation of being more warlike and courageous. They are ignorant, proud, and very scrupulous and bigoted in their religious observances. There is also a tribe called Lak or Lek, supposed by some to be Kurds, who have one of their principal seats here. In the time of Timour the courage and determination of the people of this province, who defended themselves in their strongholds and mountain fastnesses, were so great as to give that conqueror considerable trouble in subduing them. Mazanderaun is also celebrated as the scene of some of the most famous exploits of Rustom, the Persian hero. The province is traversed by an artificial causeway, extending from W. to E. nearly parallel to the Caspian; which, though built more than 200 years ago by Abbas the Great, Shah of Persia, is in very good preservation at the present day. The principal towns are,—Sari, the capital, Amol, Balfrush, and Farahabad. Pop. 150,000.

MAZARIN, JULES (properly MAZZARINO, *Giulio*), son of Pietro Mazzarino, a noble Sicilian, was born at Piscina, in the Abbruzzi, on the 14th of July 1602. Having received his elementary education at Rome, he passed into Spain with the Abbé, afterwards Cardinal, Girolamo Colonna, at the age of seventeen, where he attended courses of law in the universities of Alcala and Salamanca. But he soon abandoned jurisprudence in order to embrace the military profession, and in 1625 was sent, with the rank of captain, into the Valteline, where the pontiff then had an army. From this time he began to display his talents for diplomacy. The generals of his Holiness, Conti and de Bagni, sent him successively to the Duca de Feria, general of the Spaniards, and to the Marquis de Cœuvres, afterwards Marshal d'Estrées, who commanded the French troops; and in both missions he acquitted himself in such a manner as to merit the commendations of these chiefs. He then returned to Rome, where he resumed the study of jurisprudence, and took his doctor's degree. But the disputed succession to the duchies of Mantua and Montferrat having kindled up a new war, he quitted law for diplomacy, in which line nature had peculiarly qualified him to excel. The competitors were the Duc de Nevers, whose cause was espoused by the court of France, at which he resided, and the Duca de Guastalla, who was supported by the emperor, the King of Spain and the Duke of Savoy. The pope, desirous to prevent a war, of which Italy was about to become the theatre, sent Cardinal Sacchetti to Turin to act in favour of the Duc de Nevers; and Mazarin accompanied him in this mission. Sacchetti returned to Rome unsuccessful, leaving to Mazarin the title of internuncio, with power to continue the negotiations, and to effect a peace. Mazarin first saw Louis XIII. at Lyons in 1630, and had a long conference with Cardinal Richelieu. The cardinal entertained the highest opinio nof him, and feeling that France wanted an able and devoted man in Italy, he succeeded in gaining the young diplomatist, who from this time openly showed himself favourable to the interests of France. He returned to Italy without having obtained any success in his mission, and the war continued; but the Duke of Savoy having died, his son gave his entire confidence to Mazarin, who immediately resumed the work of peace with fresh ardour. The Spaniards were besieging Casale, and the French wished to relieve the place; but by negotiating with the chiefs of both armies he induced them to consent to an armistice for six weeks. When this truce had expired he demanded a prolongation, which the French refused, and at the same time prepared to attack the lines. Mazarin then proposed a treaty, in which they stipulated the hardest conditions. To engage them to relax in their demands, he represented the formidable state of the Spanish army, and the hazard of an attempt to force their entrenchments; but failing to persuade them, he passed over to the Spaniards, reported to them the conditions required by the French, and, still employing the same logic, urged the superiority of the French, and their ardent desire for the combat. This time he succeeded. The Spanish general assented to everything. Mazarin immediately quitted the Spanish trenches, and riding at full gallop towards the French, regardless of the balls which whistled around him, waved his hat, exclaiming "Peace, peace." The soldiers repulsed him, crying out "No peace;" but he nevertheless addressed himself to the Mareschal de Schomberg, who accepted the treaty, and caused his troops to lay down their arms. This peace was confirmed the following year by the treaty of Cherasco, which was negotiated by Mazarin. About the same time he secured to France the town of Pignerol, and deceived both the Spaniards and imperialists, who had only evacuated Casal and Mantua on condition that the French garrison should quit Pignerol. Such conduct excited against him all the hatred of the Spaniards; but it earned for him the acknowledgements of Louis XIII. and of Richelieu, who commended him favourably to the pope. Through the influence of Richelieu he was sent in 1634 to the court of France, in the capacity of nuncio extraordinary. The object of this mission was to intercede in favour of the Duke of Lorraine, who had been deprived of his estates by Louis XIII.

In 1635 the Spaniards, by their intrigues with the sovereign pontiff, procured his recal to Avignon, and even attempted to get his vice-legation revoked; but he anticipated them, and demanding his immediate recal, he in 1636 returned to Rome, where he openly supported the interests of France. He was sent to Savoy by Louis XIII. during the troubles of 1640, with the title of ambassador extraordinary. The successes of the Compte d'Harcourt in Piedmont enabled him, in December 1641, to conclude a treaty between the Duchess of Savoy and her brothers-in-law, who, supported by Spain, had disputed with her the guardianship of her son. It was then that Mazarin obtained the cardinal's hat long since demanded for him by his friend Richelieu. He was included in the nomination of the 16th December 1641, and on the 25th of February 1642 he received the cap from the hands of Louis XIII. The intrigues which had pursued Richelieu during his whole life assumed fresh force towards its close, and on his death-bed he recommended Mazarin warmly to the king, who entrusted him with the direction of all affairs of state. Richelieu had governed by terror; but Mazarin preferred to make himself friends. He obtained the release of Marshal de Bassompierre, Marshal de Vitry, and many other victims of the last minister, recalled several exiled members of parliament, and contributed to the reconciliation of the Duc d'Orleans with the king.

On the death of Louis XIII. on the 14th of May 1643, the administration of affairs was placed entirely in the hands of Mazarin. The commencement of his sway was attended with the happiest success; and the advantages gained by the king's armies secured to the cardinal the applause of the nation. But these favourable dispositions were soon succeeded by the murmurs, not loud but deep, of an oppressed people, and also by a combination of the high nobility who were jealous of his advancement and power. The civil wars of 1649, 1650, 1651, and 1652, followed; his dismissal was at length insisted on, and Mazarin immediately withdrew from the kingdom. Decree upon decree was fulminated against him; his fine library was sold; and a price was even put upon his head; yet, in spite of all the rage of his enemies, he was enabled to return to court with greater power than ever; and many who had formerly been his bitterest enemies now became his warmest friends. He put an end to the war between France and Spain, and, in order to consolidate the peace he had re-established, negotiated a marriage between the king and the infanta, which was celebrated at Sant-Jean-de-Luz on the 9th of June 1660. He died at Vincennes on the 9th of March 1661, in the fifty-ninth year of his age. Mazarin was but little regretted. A courtier writing at the time, says, "*Le roi est, ou parait, le seul touché de la mort du cardinal.*" He had accumulated immense wealth by very doubtful or equivocal means. His fortune is said to have amounted to near eight millions sterling, all acquired in a period of external war or of internal commotion. On the approach of death he felt some scruples of conscience on the subject, which were, however, soon got over.

The only productions of Mazarin which have been published are his letters. Of these, thirty-six, written by him whilst negotiating the peace of the Pyrenees, made their appearance in the year 1690; and seventy-seven more on the same subject were published in 1693. The whole were collected and reprinted at Amsterdam, in two volumes, under the title of *Negociations Secrètes des Pyrenées*. The

Abbé Allainval afterwards arranged these letters in chronological order, and, together with fifty unpublished letters, brought them out under the title of *Lettres du Cardinal Mazarin, où l'on voit le Secret de la Negociation de la Paix des Pyrenées*, Paris, 1745, in two vols. 12mo.

The character of Mazarin, who was a thorough Italian in diplomacy, has been compared, or rather contrasted with that of Richelieu, and variously shaded according to the opinions and predilections of those by whom it is delineated. "Cardinal Mazarin," says Hénault, "was as gentle as Cardinal Richelieu was violent; one of his greatest talents consisted in knowing men thoroughly. The character of his policy was rather finesse and prudence than force. He thought that force should never be employed but in default of other means; and his mind supplied the courage required by circumstances; bold at Casale, tranquil and active in his retreat at Cologne; enterprising when it was necessary to cause the princes to be arrested, but insensible to the pleasantries of the Fronde; despising the bravadoes of the coadjutor, De Retz, and listening to the murmurs of the people as one listens on the shore to the noise of the waves of the sea. There was in Cardinal Richelieu something greater, vaster, and less composed; in Cardinal Mazarin, more address, more management, and fewer extravagances. People hated the one and derided the other; but both were masters of the state."

MAZEPPA, John, the hero of one of Lord Byron's poems, was born about the middle of the seventeenth century, of a poor but noble family, in the palatinate of Podolia. At an early age he became a page at the court of John Casimir, King of Poland. After some time he returned to his native province; but engaging in an intrigue with a Polish matron of high rank, he was detected by the injured husband, and was sentenced to be bound naked on the back of an untamed horse. The animal on being let loose galloped off towards its native wilds of the Ukraine, and arrived there jaded and worn out. Mazeppa half-dead and insensible, was released from his fearful position, and restored to animation by some poor peasants. In a short time, his agility, courage, and sagacity, rendered him popular among the Cossacks. He was appointed secretary and adjutant to Samoilowich, their hetman or chief, and succeeded that functionary in 1687. The title of prince was afterwards conferred upon him by his friend and patron, Peter the Great. Bent, however, upon casting off the Russian yoke, Mazeppa became, in his seventieth year, an ally of the Swedish monarch, Charles XII. After the disastrous battle of Pultowa, fought, it is said, by his advice, he retired to Bender, and there he died in 1709.

MAZZARA, a seaport of Sicily, province of Trapani, situated on the W. coast, near the mouth of the Salemi, 11 miles S.E. of Marsala, and 26 S. of Trapani. The town is ill built; and though from the sea the domes of the churches present a fine appearance, yet when more closely approached it is found to be chiefly characterized by narrow and dirty streets. There is a public square, of a curious antique appearance, in which stand the cathedral, with a fine dome, and an equestrian statue of Count Roger the Norman (who landed here for the conquest of Sicily) over the gate; also the bishop's palace, and the senate-house. Besides these, the town contains numerous churches and convents, a college, hospital, theatre, and granary. It is surrounded by an old Saracenic wall, with small towers, and there is also an old castle in a ruinous condition. The harbour, though large, is not good, being shallow, and only accessible to small vessels. The road also is unsheltered; but notwithstanding these disadvantages the trade is considerable; and the town exports corn, wine, fruits, fish, oil, soap, &c. Pop. 8400.

MAZZOCCHI, Alessio Simmaco, an Italian writer, was born near Capua in 1684, and died at Naples in 1771. Having by dint of personal application acquired a knowledge of the Greek, Latin, and Hebrew languages, he was nominated a canon of the Neapolitan diocese, and ultimately appointed professor of biblical exegesis in the university of Naples. His name was first known among learned men through his commentary *Dell' Anfiteatro Campano*, in which he elucidates the early history of Capua, and proves, among other things, that it was the first of the eighteen Roman colonies established in Italy. In connection with his professorship he wrote a work named *Spicilegium Biblicum*, the most comprehensive of the older encyclopædias of sacred and profane learning extant; in which Homer, Hesiod, Herodotus, Plato, and most of the ancient authors, are made to contribute to the elucidation of Scripture. The other work on which Mazzocchi's fame chiefly rests is the *Commentario sopra le due tavole Eraclensi;* so called because these tablets were found in the neighbourhood of Heraclea, in *Magna Grecia*. The other works of this author are,—*De dedicatione sub ascia*, Naples, 1738; *Dissertazione sopra l'origine de' Tirreni*, Rome, 1740; *De antiquis Corcyræ nominibus schediasma*, Naples, 1742; *In vetus marmoreum S. Neapolitanæ ecclesiæ Kalendarium commentarius*, ibid., 1744; *Diatribe de librorum bipatentium et convolutorum antiquitate*, ibid.; *Opuscula oratoria, epistolæ, carmina, et diatribe de antiquitate*, ibid., 1775; an improved edition of the *Etymologia linguæ Latinæ*, by Vossius, Naples, 1762; and other less important works. (See Fabroni, *Vitæ Italorum.*) (E. F.)

MAZZUCHELLI, Conte Giovan Maria, a learned jurisconsult and biographer, born at Brescia in 1717. The first result of his studies was the *Notizie Storiche e critiche intorno alla vita e agli scritti d'Archimede*, Brescia, 1737, in which he explains the inventions of the celebrated Syracusan, and offers suggestions on the mirrors which are said to have set fire to the ships of the Consul Marcellus, and concludes by doubting the authenticity of the fact; thus anticipating the French academician, who afterwards established mathematically the argument *De falso speculo Archimedeo*. The author, encouraged by the success of this work, formed the vast design of including in one work all the literary and scientific achievements of Italy from the earliest times. Accordingly, in 1753, he published at Brescia the first two folio volumes of his work in alphabetical order, which completed the letter *A*. These were followed by four volumes on the letter *B* in 1758–63, the last which he survived to finish. He died a few years after, leaving behind him a vast collection of ancient codes, manuscripts, casts, and medals, which were afterwards engraved and given to the world, with a description by the Abbé Pietro A. Gaetani at Milan. The *Dissertazioni Storiche, scientifiche ed erudite*, 2 vols. 4to, Brescia, 1765, were the result of the *litterarie conversazioni*, or literary society, which met at his house. Count Mazzuchelli also wrote the *Vite di Scipione Capece e di Giusto de' Conti*, Brescia, 1769; *Notizie intorno ad Isotta da Imola*, ibid.; essays published in the literary periodicals of his day; many letters; and an edition of the *Vite d'uomini illustri Fiorentini di Filippo Villani*, with additions, corrections, &c. (See *Rodella*, Vita del C. G. B. Mazzuchelli, Brescia, 1766; and *Bragnoli*, Elogi de Bresciani, ibid., 1785.) (E. F.)

MEAD, Dr Richard, an eminent English physician, was born at Stepney, near London, in 1675. At sixteen years of age he was sent to Utrecht, where he studied three years under the celebrated Grævius; and then choosing the profession of physic he went to Leyden, and attended the lectures of Pitcairn and Hermann. Having visited Padua in 1695 he took his degree of doctor of philosophy and physic; and returning home he settled at Stepney, and practised physic with great success.

In 1703 Dr Mead was elected a member of the Royal Society, of which Sir Isaac Newton was then president.

The same year he was elected physician of St Thomas's Hospital, and was also employed by the surgeons to read anatomical lectures in their hall. In 1707 his Paduan diploma for doctor of physic was confirmed by the university of Oxford; and on the death of Dr Radcliffe, Mead enjoyed the most extensive practice of any physician of his day. In 1727 he was made physician to George II., whom he had served in that capacity whilst he was Prince of Wales.

During almost half a century he was at the head of his profession, and he was admired no less as a man than as a physician. His reputation, not only as a physician, but as a scholar, was so universally established, that he corresponded with the principal literati in Europe. It was principally to him that the several counties of England, and our colonies abroad, applied for the choice of their physicians, and he was likewise consulted by foreign physicians from Russia, Prussia, Denmark, and other countries. Mead's principal works are,—*A Mechanical Account of Poisons*, 1702; *De imperio Solis et Lunæ in Corpora Humana, et Morbis inde oriundis*, 1704; *A short Discourse concerning Pestilential Contagion*, 1720; *On the Scurvy*, 1749; *On Small-pox and Measles*, 1748; *Medicina Sacra, seu de Morbis insignioribus qui in Bibliis Memorantur*, 1748; *Monita et Præcepta Medica*, 1751. His works, which were written in Latin, were afterwards translated into English by Dr Thomas Slack, and received the author's revision. They passed through many editions both in this country and on the Continent. (See *Authentic Memoirs of the Life of Richard Mead*, M.D., by Matthew Maty, M.D., 8vo, London, 1755.) This great physician, naturalist, and antiquary, died on the 16th of February 1754.

MEADAY, a town of Eastern India, situated on the left bank of the River Irrawaddy, in the British province of Pegue, 35 miles N. of Prome. The frontier line, running E. and W., and separating the dominions of the King of Burmah from the recently acquired province of Pegue, passes close to this town. Lat. 19. 17., Long. 95.

MEASURES. See WEIGHTS and MEASURES.

MEATH, a maritime county in the province of Leinster in Ireland, is bounded on the N. by the counties of Cavan, Monaghan, and Louth; on the E. by the Irish Sea and Dublin county; on the S. by the counties of Kildare, Dublin, and King's County; and on the W. by Westmeath. Its superficial area is 906 square miles, or 579,899 acres, of which 547,424 are arable, 16,000 uncultivated, 12,767 in plantations, 464 in towns, and 3244 under water. Meath contains a much smaller proportion of uncultivated land than any other county in Ireland; and of the 16,000 acres of bog and coarse pasture land comprised within its boundaries, it is probable that 6000 acres are capable of improvement for cultivation, 8000 may be improved by draining, and not more than 2000 acres are unimprovable.

In the time of Ptolemy it formed part of the territory of the Eblani, whose settlement extended from the Boyne to the Liffey. According to the accounts of native writers, the district known by the name of Meath was of much greater extent than at present. It comprehended the modern counties of Meath, Westmeath, Longford, with parts of Cavan, Kildare, and the King's County, and constituted the least, but the best and most fertile, of the five subordinate kingdoms into which the island was divided. At the time of the landing of the English the O'Melaghlins ruled in Meath, and from them it was wrested by Henry II., who bestowed it on Hugh de Lacy, to be holden by the service of fifty knights. This nobleman subdivided it into twelve parts called baronies, because the persons to whom he granted those parts were afterwards created barons. In this state it continued till the reign of Henry VIII., when it was divided by act of parliament into the two counties of Eastmeath and Westmeath. The modern division of the county is into eighteen baronies. Deece, Lower and Upper; Duleek, Lower and Upper; Dunboyne; Fore; Kells, Lower and Upper; Lune; Morgallion; Moyfenrath, Lower and Upper; Navan, Lower and Upper; Ratoath; Skreen; and Slane, Lower and Upper. These baronial divisions are again subdivided into 146 parishes.

According to the ecclesiastical division of Ireland this county constitutes the greater portion of the diocese of the same name; but a few of its parishes are in the dioceses of Armagh and Kilmore. There were formerly many episcopal sees in Meath, all of which, except Kells and Duleek, which, however, subsequently shared the same fate as the others, were consolidated previously to the year 1152, when Cardinal Paparo settled the diocesan divisions of Ireland, by authority from Pope Eugenius III. The seat of the see was then fixed at Clonard. The bishopric of Clonmacnois was united to it by act of parliament in 1568. The bishop of Meath has no cathedral church; his residence has for a long period been at Ardbraccan, about 3 miles from Navan, which in the wars of 1641 was a castle of considerable strength, but is now a tasteful modern mansion, and one of the finest of the episcopal palaces in Ireland. The constitution of the diocese possesses many singularities. There is neither dean nor chapter. The only dignitaries are the dean of Clonmacnois, and the archdeacon of Meath. The want of a chapter is supplied by a synod, of which every beneficed clergyman within the diocese is a member. This synod has a common seal, which is lodged in the hands of members annually selected for its custody. The Bishop of Meath takes precedence of all the other suffragan bishops in Ireland, and is a member of the privy council in right of his see.

The surface of this county, though generally level, is yet not without its characteristic beauties. The banks of the Boyne, especially, present a succession of prospects in which the undulating surface is richly ornamented with the natural beauties of wood and water, studded by numerous buildings, both ancient and modern. Few of the elevations are of sufficient height to be termed hills, except Slieve Naccalliagh (904 feet), and Lloyd (422 feet), in Kells barony; and even these, where cultivated, are productive to their summits. The latter is surmounted by a pillar 100 feet in height, erected by the first Earl of Bective, from which a fine view of the rich level plain of Meath may be obtained.

The River Boyne enters the county at its south-western extremity, and intersects it diagonally in a north-eastern direction, pursuing a quiet gentle course, through a rich and fertile country, till it discharges itself into the sea below Drogheda, where it forms the boundary between the counties of Meath and Louth. It receives the Blackwater at Navan. The Moynalty or Borora is a branch of the Blackwater. The Nannywater discharges itself into the Irish Sea. The Ryewater forms part of the boundary between Dublin and Meath. The Boyne is navigable for barges as far as Navan, whence a canal has been carried to Trim. The Royal Canal touches the southern border of the county between Kilcock and Cloncurry. The sea-coast is confined to the short space between the mouth of the Boyne and the stream of the Delvin, which is part of the boundary of Dublin county. It presents a shelving strand, without a port of any consequence. There is no sheet of water meriting the name of lake, except that of Lough Sheelin, which bounds the county on the N., being situated partly also in the counties of Cavan and Westmeath, and the very inconsiderable Lough of Lakefield, in Demifore.

The soil is extremely variable, being found of every quality, from a deep rich loam to the lightest sandy earth; but that most generally to be met with is a strong deep clay, resting on a substratum of limestone gravel. In some parts, and even on the tops of the hills, as good earth has been found at the depth of 4 feet as at the surface.

The county is wholly included within the great central plain of floetz limestone, which crosses Ireland in a broad band. The mineral productions are few, owing partly to the character of the soil, and partly to that of the surface, which, from its general flatness, prevents the interior from being explored to any depth, without being impeded by subterraneous water. A copper mine was for some time worked in Skreen barony, but the latter of the causes now mentioned put a stop to the operations. Limestone of large scantling, well suited for building purposes, and also susceptible of a high polish, is raised at Ardbraccan. It is white when fresh from the chisel, but assumes a greyish hue from atmospherical exposure. Argillaceous clay, which has been applied to the manufacture of coarse earthenware, is raised in some places. In Slane barony *coal-smut* has been found in abundance, at the edges of streams, where the soil has been washed away by the action of the water; but coal has not yet been discovered.

The population of a district enjoying so many of the natural advantages suited to the maintenance of human existence, was probably in early times more numerous than in most other parts of the kingdom; but in consequence of the conversion of the greater portion of its surface into pasture land, the operation of the clearance system has for some time past reduced the number of its inhabitants, in proportion to the extent of cultivated land, to much less than in any other Irish county.

The population of the county in modern times has been stated as follows:—

1760	De Burgo	81,516
1792	Beaufort	112,400
1812	Par. return	142,579
1821	Do.	159,183
1831	Do.	176,826
1841	Do.	183,828
1851	Do.	140,750

Meath returned no fewer than fourteen representatives to the Irish parliament,—two for the county at large, and two for each of the boroughs of Trim, Navan, Athboy, Duleek, Kells, and Ratoath. This number was reduced to two at the Union, all the representatives for boroughs having been struck off.

In 1851 the number of schools and of pupils attending them during the week ending 12th April was:—

Schools.	No. of Schools.	No. of Children.		
		Males.	Females.	Total.
National	82	2730	2690	5420
Church Education	6	96	62	158
Endowed	6	495	490	985
Boarding	2	111	...	111
Private	54	876	610	1486
Parochial	13	179	125	304
Free	12	143	234	377
Workhouse	7	945	896	1841
Gaol	1	87	...	87
Total	183	5662	5107	10,769

There are charter-schools at Trim and Ardbraccan, a school endowed at Navan by a bequest of Alderman Preston in 1686, and a large free school was established at Oldcastle by a bequest of Mr Gibson of London.

The population is chiefly engaged in agriculture. The soil being principally composed of a deep rich earth, the deepest ploughing is considered as the best tillage. A complete summer's fallow at stated intervals is considered necessary to keep the land thoroughly clean; every other attempt to eradicate the weeds, by means of clover, vetches, or any other umbrageous green crop, having proved ineffectual. Planting potatoes, even without manure, is considered as a good method of fallowing where cleansing is the only object. In the neighbourhood of villages it is a common practice for farmers to throw open the field which he intends to fallow to the cottagers, who furnish manure and plant their potatoes on it. If the ground be in good heart, he charges them at the rate of somewhat more than his own rent, which is termed "paying the standing rent;" but if poor, he makes no charge. With respect to the rotation of crops, or system of cropping, no restriction is imposed on the tenant. Every one is permitted to raise that kind of grain from which he expects to derive the greatest produce.

The crops usually cultivated are,—wheat, oats, barley, bere, rye, clover, flax, potatoes, cabbage, rape, turnips, and pease. The red wheat is preferred by most as agreeing best with the soil, and having a thinner rind, bearing the change of season better, and being less apt to lodge than the white. The latter is cultivated on the lighter and more gravelly soils. It comes in earlier, but is more liable to injury from the weather or mildew. Oats are produced in the greatest variety and of the finest samples. Barley is sown on the richest land, and requires the nicest tillage; and it is considered as one of the most profitable crops. Bere is a good deal sown, particularly after potatoes; it is also a profitable crop where it succeeds, but it is uncertain. The straw makes excellent fodder for young cattle. Rye, by itself or mixed with wheat, when it is called *meslin*, is chiefly ground into whole meal for domestic consumption. Flax is mostly sown in small patches for the use of the farmer's family, and seldom offered in quantities for sale; it grows strong and luxuriant, so as to be seldom fitted for the finer fabrics. When a field is laid down for grass, those parts of it on which flax had been grown produce the most luxuriant herbage, and show the earliest verdure in the following year. Rape is grown with the greatest success on bog which has been reclaimed by burning. Red clover is much used as a renovating crop; white clover is seldom sown except on land laid down for pasture.

The total extent of land under each description of crop in 1855 and 1856 was as follows:—

	1855.	1856.
Wheat	18,764	23,398
Oats	86,831	78,302
Barley, bere, rye, beans, and pease	4,876	3,633
Potatoes	19.235	21,898
Turnips	9,904	9,261
Other green crops	4,005	4,007
Flax	266	213
Meadow and clover	64,646	60,557
Total	208,527	201,269

The quantity of artificial grass sown is very small, as compared with the extensive tracts producing natural grasses; the depth and richness of the soil throughout almost the whole of the county, and its tendency to moisture without being absolutely wet, making it throw up a coat of nourishing herbage scarcely equalled in Ireland. In other counties there are districts which far exceed the richest lands here; such are the Golden Vale in Tipperary, and the corcass lands in Limerick. But no other district can exhibit 560,000 acres in close proximity of such excellent quality, and so appropriate to every purpose of tillage and pasture, as Meath. It is, generally speaking, more friendly to the latter kind of agriculture, and consequently was almost wholly applied to grazing, until the legislative measures adopted by the Irish parliament for the encouragement of tillage induced many to break up the large tracts which for ages had continued untouched by the ploughshare. The superior excellence of the beef reared here over that of any other district has made the county proverbial for its feeding. All the old pastures are composed of grasses of the best kinds. Graziers seldom think of procuring any particular species, from an opinion that the land, after three years, will revert to its natural herbage, even though grasses of other kinds had been sown upon it when laid down. Dry gravelly soils throw up a rich coat of white clover, though no red has been sown; and grounds of a clayey nature, when drained and manured with limestone gravel, often exhibit a similar tendency. Natural meadows are to be met everywhere; few farms, whatever be their size, are without a sufficiency for the holder's use. The artifical grasses chiefly cultivated are clover and trefoil. Much attention is paid by the graziers to the treatment of their feeding stock. The first week in May the pastures are generally opened for the summer stock, which are seldom reared here, the land being deemed too valuable to be given up to young cattle. Beasts of this description are brought from Connaught or Munster. When they arrive they are bled and turned into the pasture-field, where they remain till completely fattened, each field being stocked at once with its full complement. They are then sold partly in the Dublin market for the consumption of the metropolis, or for exportation to Liverpool. The sheep, like the cattle, are seldom bred in the country, but are bought at the October fair of Ballinasloe. Lands newly laid down are generally appropriated to the rearing of lambs for the Dublin market.

The quantity of live stock in the county of Meath in 1855 and 1856 was—

	1855.	1856.
Horses	23,310	23,646
Cattle	135,485	140,813
Sheep	170,582	189,029
Pigs	22,425	17,546

There are about 11,000 holdings exceeding one acre in extent, and most of the farmers occupying from 30 to 100 acres keep a few cows, the produce of which, both in milk and butter, that remains after supplying their own families, is sent to market. There are also a number of dairy farms in Dunboyne and Ratoath, on which the landlord supplies the land, houses, and stock; the tenant furnishes labour and utensils, and pays for the mowing and hay making. Cheese is very seldom made, and only for domestic use.

The quantity of natural wood throughout the country is small, but the plantations in demesnes and about gentlemen's seats, are numerous and thriving. The trees most usually met with are ash, elm, sycamore, lime, and larch. Scotch and spruce fir are less common. The oak is very scarce, the principal growth of it being at Loughcrew, in Demifore. There are many osieries, of from 2 to 10 acres each, the produce of which is sold to the basket-makers of Dublin.

The manufactures are chiefly confined to the making of sacking from tow, of course linens in the neighbourhood of Drogheda, where the cotton manufacture is also carried on to some extent, and of linens of a texture somewhat finer in the western baronies. Some coarse frieze is also manufactured for home consumption. There are paper manufactories, distilleries, breweries, and tanyards in several localities, but the number of persons in this county employed in manufacturing occupations is very small. The chief outlet for the produce of the county is Drogheda. There are good markets for grain and provisions at Trim and Navan, and extensive flour-mills on the Boyne and Blackwater.

There are several mansions in this county of great size and splendour, surrounded by highly improved demesnes, and numerous seats of resident gentlemen. The farm houses are generally of very inferior construction, formed of the earth or clay taken off the surface of the spot on which the house is to be built; hence the floor is commonly several inches below the level of the soil, and consequently damp and unwholesome. The habitations of the labourers and cottars are of a description still worse, being built of mud, and often with sunken floors. The owners of some estates, however, have provided comfortable residences for their labourers, to be held by them on moderate terms. In many parts the lower classes suffer from want of fuel; bog-land being extremely scarce, and the expense of carriage precluding the purchase of coal, which must be drawn from Dublin or Drogheda.

The peasantry of Meath are generally a fine, well-looking and healthy race, but more phlegmatic and serious than the inhabitants of the mountain districts of Ireland; and owing to the early occupation of this portion of the country, and its situation within the English pale, the admixture of races is very great.

Amongst the most ancient remains of antiquity may be mentioned the round or pillar towers at Kells and Donaghmore. The former is a very perfect specimen of these peculiar structures, 99 feet high, and has four small apertures near the top facing the four cardinal points of the compass. The latter, also very perfect, is remarkable for having a representation of the Saviour on the cross, carved on the key-stone over the entrance, which some antiquaries consider a decided proof that these structures were not built by the pagans; while others, anxious to support the theory of the pagan origin and the antiquity of the Irish round towers, assert that this doorway is not the original one. At Kells is a fine ancient sculptured cross of beautiful workmanship, and another of plainer construction at St Kieran, about 3 miles from Kells. At New Grange, near Slane, is a pagan relic of great interest, consisting of an artificial cavern or underground gallery, in the form of a cross, 71 feet in its greatest length, 20 feet between the extremities of the arms of the cross, and 11 feet in its greatest height, surrounded by a tumulus or hillock raised by art, which is surrounded by a circle of huge unhewn stones set upright. "It is," says Dr Wilde in his interesting work on the beauties of the Boyne and the Blackwater, "probably one of the oldest Celtic monuments in the world, which has elicited the wonder and called forth the admiration of all who have visited it, and has engaged the attention of nearly every distinguished antiquary, not only of the British Isles, but of Europe generally." It is supposed to have been either a place of Druidical worship or a burying-place; and two skeletons, uncovered with earth, were found in it when first opened. The Hill of Tara, a few miles S. of Navan, is famous as being the place where the kings of Ireland were crowned, and where the states of the island held their triennial assemblies, called the Fez of Tara. The traces of some of the localities supposed to have been connected with this ancient custom, are said by some antiquaries to be still discoverable on it. On the summit of the sacred hill, which is 512 feet above the level of the sea, is a rath called the Rath of the Synods, or the King's Chair, and at a short distance a larger rath called the King's Rath. Other raths are to be seen at Lismullen, Odder, and Ringlestoun. Columbkill's House, a stone-roofed crypt or cell at Kells, is said to be the most ancient building of that material in Ireland. The ruins of monastic buildings scattered throughout the county are too numerous to admit even of recapitulation. Trim had seven monastic institutions; Kells, Killeen, Duleek, and Skryne, three each. Several of these buildings have been converted into parish churches. The ruins of ancient castles are not less numerous. Some of them have been altered into modern residences. Of these Slane Castle, the seat of the Marquis of Conyngham, is conspicuous both for architectural structure and beautiful situation on a richly wooded elevation overhanging the Boyne. It was a favourite spot with King George IV. during his visit to Ireland in 1821. Killeen Castle, the seat of the Earl of Fingal, in addition to its claims on the score of antiquity, is memorable as having afforded an asylum during the rebellion of 1798 to the well-affected of every description. The clergymen, both Protestant and Catholic, performed divine service there under the same roof as long as danger existed.

Meaux
Mecca.

The principal towns of Meath are Navan, Kells, and Trim, the county town, none of which has a population above 4000. These towns will be found described under their respective heads. (H. S—R.)

MEAUX, a town of France, capital of an arrondissement of the same name in the department of Seine-et-Marne, is situated on the Marne, 25 miles E.N.E. of Paris. It is well built, though not very regularly laid out; and contains a fine cathedral, built in the eleventh century, and dedicated to St Etienne, but which is in an imperfect state, having only one complete tower in the front. Besides this, the principal buildings are,—the episcopal palace, a library with 13,000 volumes, a college, town-hall, and theatre. The chief articles of manufacture are,—cotton, earthenware, glue, flour, leather, and saltpetre; and the trade is considerable in grain and cheese. Meaux is an ancient city, occupying the site of *Iatinum*, the capital of the Meldi, from whom the city derives its modern name. It is, however, chiefly notable as the see of the celebrated Bossuet, who became bishop in 1681, and continued in that office till his death in 1704. His remains are deposited in the cathedral, where there is also a monument of white marble erected to his memory. When his tomb was opened in 1854, the body of the illustrious prelate was found in a very good state of preservation. Pop. (1851) 8356.

MECCA, MECCAH, or MEKKA, a city of Arabia, capital of the province of El Hejaz, is situated in a narrow valley stretching N. and S., 70 miles E. of Jiddah, its port on the Red Sea; Lat. 21. 30. N., Long. 40. 8. E. It is very closely confined between bare hills from 200 to 500 feet high, and is built in a strong and substantial manner, the principal materials being brick, granite, and sandstone quarried from the neighbouring hills. The length of the city and suburbs from N. to S. is about 2½ miles; and its broadest part is three-quarters of a mile from E. to W. Near the centre stands the famous mosque containing the Kaabah, to which Mecca owes its sanctity in the eyes of the followers of Mohammed. The densest part of the town is on the slope of the hill to the E., called Abu Kubays. Mecca was formerly walled on three sides, but is now only defended by the hills which inclose it, and by a strong square castle situated on a rising ground called Jiyad, to the S. The position of the city has been compared by Lieut. Burton to that of Bath, and by others to that of Florence, though vastly inferior to either, and especially to the latter, in beauty. The houses are in general three storeys in height; and, contrary to the usual custom in eastern towns, they have windows in front opening into the street. Most of the houses are fitted up for the accommodation of pilgrims who frequent the holy shrine at Mecca, and consist of a number of separate lodgings, each containing a sitting-room and a kitchen. On the roofs of the houses there are terraces surrounded by parapets, which conceal their occupants from view. The streets are wide, but unpaved, and in rainy weather are extremely muddy. The city is remarkably destitute of public buildings,—a fact which Burckhardt has accounted for by the reverence with which the shrine of their religion is regarded by all true Mohammedans. This building, which is called by the Moslems *Bait Ullah* (the House of Allah) or *Kaabah* (the Cube or Square House), stands in the centre of the mosque, a large open court of an irregular oblong form. Although the outer walls of the mosque are not perfectly straight, the unsymmetrical appearance of the exterior is removed by a colonnade of a more regular form which runs round the inside. The size of the mosque is, according to the measurement of Lieutenant Burton, 257 paces by 210, although most of the Moslem authorities make it considerably less. The pillars of the colonnade which are ranged along the east wall in four rows, and on the other three sides for the most part only three deep, are more than 20 feet high and about 1½ in thickness, and are crowned with capitals of Saracenic architecture, of which no two can be found exactly alike. The materials of which they are composed are white marble, granite, and sandstone. As little regard has been paid to uniformity in the arrangement of these pillars as in their substance and workmanship; it has therefore been found no easy task for visitors to ascertain their exact number, but there are probably between 550 and 600 in all. Springing from every four columns may be seen a small dome, plastered and whitewashed on the outside; and seven minarets, as well as many towers and pinnacles, are placed among the cloisters and at the corners. The number of the domes is said to be 152; and it is stated that there are in all 1352 towers and pinnacles on the walls. The minarets and several other parts of the walls and arches are painted in bright colours; but there are no representations of flowers, such as are usually to be met with in Mohammedan mosques. The floor of the cloisters is paved with large stones, and eight raised pavements of the same sort extend from the outside to the middle of the area, where stands the Kaabah. They have a sufficient breadth to allow four or five persons to walk abreast, and are raised about 9 inches above the rest of the ground; serving at once as passages to the central shrine and as partitions to separate the spaces allotted to the different classes of worshippers. Near the centre of the inclosure stands the Kaabah, an oblong edifice of fine grey granite, which, according to Burton, is 55 feet in length by 45 in breadth. Its height appeared to that traveller to exceed its length; but Burckhardt states it as between 35 and 40 feet. The ground on which it stands is slightly inclined, and the roof also has a slope, so as to allow the water to run off, but not so much as to prevent the entire building from having the general appearance of a cube, from which it derives its name. It is surrounded by a covering of black silk hanging from the roof, with a golden band running round the top, and a golden curtain in front of the door. The *Hajar el Aswad*, or Black Stone, which is the object of so much adoration on the part of pilgrims and devotees, stands at the east corner of the building, at a height of 4 or 5 feet from the ground, and is composed of a number of small stones well cemented together and carefully smoothed, presenting the appearance of having been violently broken in pieces and then mended. The constant wear which the stone has undergone from the lips and hands of the superstitious worshippers has rendered it extremely difficult to tell the nature of the material; but most travellers are agreed that it is of volcanic origin, and Lieutenant Burton expresses his conviction that it is a large aerolite. The door of the Kaabah, by which free admission is granted only ten or twelve times a year, is in the north-west side, about 7 feet from the ground, not far from the Black Stone, and is covered with silver, and adorned with ornaments of gold. There is a flight of steps of carved wood by which entrance is gained to the temple, and which is moved away on rollers and placed at a distance when not used. The interior is plain, and destitute of windows or any other opening besides the entrance, except a small door, called the *Bab el Taubah*, or Gate of Repentance, leading to a staircase by which the attendants gain access to the roof. The floor and walls consist of a sort of chequer-work of marble of various colours, principally white; and the roof and top part of the walls are covered with red damask embroidered with gold. In the roof there are three cross rafters resting on the north-eastern and south-western sides, and on three pillars in the centre. Between these, at the height of about 9 feet, there is a metal bar from which many lamps are hung; and the only other article of furniture in the apartment is a small press in one corner, in which the key of the building is some-

Mecca.

times placed. On the outside, in the south-west wall, there is a stone, distinguished from the rest by its dark red colour, which, as well as the Black Stone, is touched and kissed by the devotees. Not far from the door there is a small hollow, paved with marble, where it is reckoned an act of merit to pray, as being the place where Abraham and Ishmael are said to have kneaded the cement for building the Kaabah. It is called *El Maajan,* the Place of Mixing or Kneading. On the N.W. side of the Kaabah are said to be situated the graves of Ishmael and Hagar, inclosed by a semicircular wall 5 feet high and 4 thick, covered with white marble. Round the Kaabah is an oval inclosure, well paved with marble, and surrounded by thirty-two iron posts, connected by rods, which support many lamps, said to exceed 1000 in number. Outside of this inclosure there are two broad steps, which rise from the level of the Kaabah to that of the surrounding area. Nearly opposite to the four sides of the central building stand four *makams*—small buildings, somewhat like Indian pagodas, for the accommodation of the imams of the four orthodox sects in conducting the devotions of their adherents, who take their seats near their respective imams. One of these makams contains a stone which is said to bear the impress of Abraham's foot. The *Zem Zem,* or Sacred Well, believed to be that of Hagar, is inclosed in a square substantial building opposite the east corner of the Kaabah, and near one of the four makams. The interior of this edifice is adorned with marble of various colours, so as to have a beautiful appearance, and the well itself is surrounded by a circular wall 5 feet high and 10 in diameter. The origin of the name *Zem Zem* is doubtful; but the water is believed by the Moslems to possess great virtues, although its taste is far from pleasant, and it is apt to cause diarrhœa and boils. Jars of this water are placed in rows throughout the area of the mosque. There are two other buildings in the sacred inclosure, which stand to the north-east of the Zem Zem, and are used, the one to contain the clocks sent hither by the sultan, and the other the MSS. belonging to the mosque. These buildings are called *El Kobbateyn,* and are very heavy looking, agreeing ill with the light and elegant structure of the makams. The *mambar,* or pulpit, stands opposite to the front of the Kaabah, and is an elegant structure of white marble, ascended by a straight and narrow stair from behind, and surmounted by a gilt pinnacle in the form of an obelisk. The mosque is entered by nineteen gates, most of which have two or three arches; and as none have doors, it is open at all times. The outside walls are those of the adjoining houses, which, though originally the property of the mosque, have now fallen into the hands of private individuals, and are let to the richer pilgrims, who are allowed to perform their devotions at home, if within sight of the Kaabah.

Such is the famous mosque of Mecca; a building which is as much an object of reverence to Mohammedans as the Holy Sepulchre to Catholics, and which, like that also, has furnished the model of many other places of worship. Christians are not allowed to enter, and would incur serious danger if discovered within the pale of the sacred edifice; but this has not hindered enterprising travellers from penetrating its mysteries in the disguise of pilgrims. In this manner it has been visited by Burckhardt, Badia, and Burton, all of whom have embodied the result of their observations in pretty full accounts of the celebrities of Mecca. Besides the mosque, Mecca contains the palace of the sherif,—a large whitewashed building with wooden balconies, but in no way very remarkable. It stands in the northern suburb of the town; and not far off there is a deserted house, once the abode of the Sherif bin Aun, but now said to be haunted. The Meccans also show in the town the birthplace of the prophet, the house in which he lived, and many other localities connected with various recorded events of his life. All these places are visited by the pilgrims with great attention and respect. The cemetery of Mecca, called *Jannat el Maala,* is also much frequented by devotees, as it contains the tombs of Mohammed's mother and of his first wife, as well as those of many other Moslem saints. It is a bare piece of ground at the foot of the western hills, surrounded by a rude wall, and entered through a mean-looking gateway. About 12 miles to the E. of Mecca stands Mount Arafat, which is a place visited by all the pilgrims to Mecca, and on which certain devotions are performed, and a sermon preached to the pilgrims. It rises from a sandy and gravelly plain to the height of 180 or 200 feet; and the plain is covered during the ceremony with the tents of the pilgrims. The numbers present on these occasions are believed by the Arabs to be never less than 600,000, as there is a tradition that when they do not make up this number the angels descend to complete the assemblage. It was calculated, however, by Burton in 1853, that there were only 50,000; and in the following year the number fell to 25,000. Another place visited by pilgrims is Muna, between Arafat and Mecca, where there is a rude piece of masonry in a narrow and rugged defile. The ceremony performed here forms the concluding act of the pilgrimage: it consists of throwing small pebbles and muttering certain words, and is called *stoning the devil.* The inhabitants of Mecca are little employed in manufactures, but a considerable trade is carried on, especially during the season of pilgrimage. Pop. about 45,000.

MECHAIN, Pierre François André, a practical astronomer and geographer, was born at Laon on the 16th April 1744. His father, who was an architect, educated him for his own profession, but he accidentally became acquainted with Lalande, under whose patronage he was subsequently brought forward as an observer, surveyor, and computer. He made two voyages with M. de la Bretonnière, and assisted him in surveying some parts of the coast of France. He was afterwards employed in various computations by the Marquis de Chabert and the Duc D'Ayen. Having obtained a prize from the Academy of Sciences in 1782, for a Memoir on Comets, he became a member of the Academy the same year. About the year 1785 he undertook the publication of the *Connaissance des Tems,* and continued it till he was employed in geodetical operations at a distance from Paris. He was appointed member of a committee, along with Cassini, De Thury, and Legendre, to meet the English astronomers for the determination of the relative situation of the observatories which had been proposed by Cassini. It was in these operations that he first brought Borda's circle into general use. In 1791 he was appointed, in conjunction with Delambre, to execute the intentions of the Constituent Assembly with regard to the determination of a basis of linear measures. He was made director of the observatory of Paris, and he entered with great zeal on a series of observations which were to rival those of Flamsteed, Bradley, and Maskelyne; but he afterwards solicited the appointment to assist in the measurements required for the still farther extension of the arc of the meridian to the S. of Barcelona. But the secret motive for his seeking this humbler employment appears to have been a desire to remove some doubts which he entertained respecting the latitude of Barcelona, as it appeared after his death from his papers that there had been a discordance of 3″ in some previous observations. Shipwreck and disease awaited him, however, and he died of fever on the 20th September 1805.

Of his publications the most important are to be found in the *Mémoires des Savans étrangers;* also a Memoir on the Comets of 1532 and 1661, which gained the prize. In the Memoirs of the Academy, and in the *Connaissance des Tems,* from 1782 to 1785, there are several of his observations.

MECHANICS.

1. Mechanics, *Applicate* or *Applied*, is a term which, strictly speaking, includes all applications of the principles of abstract mechanics to human art.[1] As in other branches of knowledge, so in mechanics, art is more ancient than science, many mechanical inventions having been introduced into practice ages before the general principles of their action were discovered; but also, as in other branches of knowledge, so in mechanics, science is necessary to the perfecting of art, and mechanical inventions have in all cases continued rude, wasteful, and inefficient, until their dependence on general principles has been understood. Thus have theory and practice in all ages promoted each others' advancement; and the greatest obstacle to the advancement of both has always been a popular and scholastic fallacy that they are inconsistent. Happily that fallacy is now disappearing, and its occurrence in the writings of any author may be considered as a mark either of ignorance, or of the inconsiderate use of words.

2. *Divisions of the Subject—Structures and Machines.*—The practical applications of Mechanics may be divided into two classes, according as the assemblages of material objects to which they relate are intended to remain fixed or to move relatively to each other; the former class being comprehended under the term "Theory of Structures," and the latter under the term "Theory of Machines." As the details of the theory of structures are amply set forth in this Encyclopædia, in the articles relating to the art of Construction,—such as Aqueduct, Arch, Brickmaking, Bridge, Building, Carpentry, Centre, Dock, Drainage, Embankment, Fortification, Harbours, Iron, Iron Bridges, Joinery, Masonry, Naval Architecture, Railroads, Strength of Materials, &c.,—that theory will be treated of in the present article to such extent only as may be necessary in order to state certain general principles applicable to all these subjects. The greater part of the article will relate to machines.

PART I.—OUTLINE OF THE THEORY OF STRUCTURES.

3. *Support of Structures.*—Every structure, as a whole, is maintained in equilibrio by the joint action of its own *weight*, of the *external load* or pressure applied to it from without and tending to displace it, and of the *resistance* of the material which supports it. A structure is supported either by resting on the solid crust of the earth, as buildings do, or by floating in a fluid, as ships do in water and balloons in air. The principles of the support of a floating structure form an important part of the science of Hydrodynamics, and of the arts of Aeronautics and Naval Architecture, to the articles under which titles the reader is referred. The principles of the support, as a whole, of a structure resting on the land, are so far identical with those which regulate the equilibrium and stability of the several parts of that structure, and of which a summary will presently be given, that the only principle which seems to require special mention here is one which comprehends in one statement the power both of liquids and of loose earth to support structures, and which was first demonstrated in a paper "On the Stability of Loose Earth," read to the Royal Society on the 19th of June 1856, and published in the *Philosophical Transactions* for that year, viz.:—

Let E represent the weight of the portion of a horizontal stratum of earth which is displaced by the foundation of a structure; S the utmost weight of that structure, consistently with the power of the earth to resist displacement; ϕ the angle of repose of the earth; then

$$\frac{S}{E}=\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2.$$

To apply this to liquids, ϕ must be made $= 0$, and then $\frac{S}{E}=1$, as is well known.

4. *Composition of a Structure, and Connection of its Pieces.*—A structure is composed of *pieces*,—such as the stones of a building in masonry, the beams of a timber frame-work, the bars, plates, and bolts of an iron bridge. Those pieces are connected at their *joints* or surfaces of mutual contact, either by simple pressure and friction (as in masonry with moist mortar or without mortar); by pressure and adhesion (as in masonry with cement or with hardened mortar, and timber with glue); or by the resistance of *fastenings* of different kinds, whether made by means of the form of the joint (as dovetails, notches, mortises and tenons); or by separate fastening pieces (as trenails, pins, spikes, nails, holdfasts, screws, bolts, rivets, hoops, straps, and sockets).

5. *Stability, Stiffness, and Strength.*—A structure may be damaged or destroyed in three ways,—first, by *displacement* of its pieces from their proper positions relatively to each other or to the earth; secondly, by *disfigurement* of one or more of those pieces, owing to their being unable to preserve their proper shapes under the pressures to which they are subjected; thirdly, by *breaking* of one or more of those pieces. The power of resisting displacement constitutes *stability;* the power of each piece to resist disfigurement is its *stiffness;* and its power to resist breaking, its *strength.*

6. *Conditions of Stability.*—The principles of the stability of a structure can be to a certain extent investigated independently of the stiffness and strength, by assuming, in the first instance, that each piece has strength sufficient to be safe against being broken, and stiffness sufficient to prevent its being disfigured to an extent inconsistent with the purposes of the structure, by the greatest forces which are to be applied to it. The condition that each piece of the structure is to be maintained in equilibrio by having its gross load, consisting of its own weight and of the external pressure applied to it, balanced by the *resistances* or pressures exerted between it and the contiguous pieces, furnishes the means of determining the magnitude, position, and direction of the resistances required at each joint in order to produce equilibrium; and the *conditions of stability* are, first, that the *position*, and secondly, that the *direction*, of the resistance required at each joint shall, under all the variations to which the load is subject, be such as the joint is capable of exerting,—conditions which are fulfilled by suitably adjusting the figures and positions of the joints, and the *ratios* of the gross loads of the pieces. As for the *magnitude* of the resistance, it is limited by conditions, not of stability, but of strength and stiffness.

7. *Principle of Least Resistance.*—Where more than one system of resistances are alike capable of balancing the same system of loads applied to a given structure, it has been demonstrated by Mr Moseley, that the *smallest* of those alternative systems is that which will actually be ex-

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[1] For the exposition of the principles of abstract mechanics, see the articles Dynamics and Statics.

erted;[1] because the resistances to displacement are the effect of a strained state of the pieces, which strained state is the effect of the load, and when the load is applied the strained state and the resistances produced by it increase until the resistances acquire just those magnitudes which are sufficient to balance the load, after which they increase no further.

This "principle of least resistance" renders determinate many problems in the statics of structures which were formerly considered indeterminate.

8. *Relations between Polygons of Loads and of Resistances.*—In a structure in which each piece is supported at two joints only, the well-known laws of statics show that the directions of the gross load on each piece, and of the two resistances by which it is supported, must lie in one plane,—must either be parallel, or meet in one point,—and must bear to each other, if not parallel, the proportions of the sides of a triangle respectively parallel to their directions; and if parallel, such proportions that each of the three forces shall be proportional to the distance between the other two; all the three distances being measured along one direction.

Considering, in the first place, the case in which the load and the two resistances by which each piece is balanced meet in one point, which may be called the *centre of load*, there will be as many such points of intersection, or centres of load, as there are pieces in the structure; and the directions and positions of the resistances or mutual pressures exerted between the pieces will be represented by the sides of a polygon joining those points, as in fig. 1, where P_1, P_2, P_3, P_4, represent the centres of load in a structure of four pieces; and the sides of the *polygon of resistances* $P_1P_2P_3P_4$ represent respectively the directions and positions of the resistances exerted at the joints. Further, at any one of the centres of load let PL represent the magnitude and direction of the gross load, and P*a*, P*b* the two resistances by which the piece to which that load is applied is supported; then will those three lines be respectively the diagonal and sides of a parallelogram; or, what is the same thing, they will be equal to the three sides of a triangle; and they must be in the same plane, although the sides of the polygon of resistances may be in different planes.

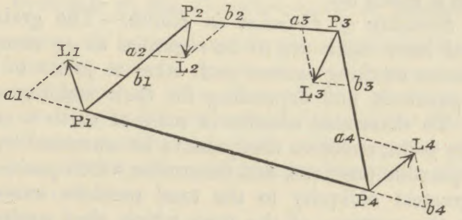

Fig. 1.

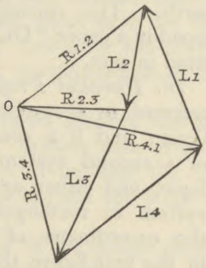

Fig. 2.

According to a well-known principle of statics, because the loads or external pressures P_1L_1, &c., balance each other, they must be proportional to the sides of a closed polygon drawn respectively parallel to their directions. In fig. 2 construct such a *polygon of loads* by drawing the lines L_1, &c., parallel and proportional to, and joined end to end in the order of, the gross loads on the pieces of the structure. Then from the proportionality and parallelism of the load, and the two resistances applied to each piece of the structure, to the three sides of a triangle, there results the following—

THEOREM.—*If from the angles of the polygon of loads there be drawn lines* ($R_{1,2}$, &c.), *each of which is parallel to the resistance* (as P_1P_2, &c.) *exerted at the joint between the pieces to which the two loads represented by the contiguous sides of the polygon of loads* (such as L_1, L_2, &c.) *are applied; then will all those lines meet in one point* (O), *and their lengths, measured from that point to the angles of the polygon, will represent the magnitudes of the resistances to which they are respectively parallel.*

(The particular case of this theorem which relates to a system of parallel vertical loads, has long been known; but in its general form the theorem is now published in type for the first time, having appeared originally in a lithographed abstract of some lectures.)

When the load on one of the pieces is parallel to the resistances which balance it, the polygon of resistances ceases to be closed, two of the sides becoming parallel to each other and to the load in question, and extending indefinitely. In the polygon of loads the direction of a load sustained by parallel resistances traverses the point O.

9. *How the Earth's Resistance is to be treated.*—When the pressure exerted by a structure on the earth (to which the earth's resistance is equal and opposite) consists either of one pressure, which is necessarily the resultant of the weight of the structure and of all the other forces applied to it, or of two or more parallel vertical forces, whose amount can be determined at the outset of the investigation, the resistance of the earth can be treated as one or more *upward loads* applied to the structure. But in other cases the earth is to be treated as *one of the pieces of the structure*, loaded with a force equal and opposite in direction and position to the resultant of the weight of the structure and of the other pressures applied to it.

10. *Partial Polygons of Resistance.*—In a structure in which there are pieces supported at more than two joints, let a polygon be constructed of lines connecting the centres of load of any continuous series of pieces. This may be called a *partial polygon of resistances.* In considering its properties, the *load* at each centre of load is to be held to *include* the resistances of those joints which are *not* comprehended in the partial polygon of resistances, to which the theorem of section 8 will then apply in every respect. By constructing several partial polygons, and computing the relations between the loads and resistances which are determined by the application of that theorem to each of them, with the aid, if necessary, of Mr Moseley's principle of the least resistance, the whole of the relations amongst the loads and resistances may be found.

11. *Line of Pressures—Centres and Line of Resistance.*—The *line of pressures* is a line to which the directions of all the resistances in one polygon are tangents. The *centre of resistance* at any joint is the point where the line representing the total resistance exerted at that joint intersects the joint. The *line of resistance* is a line traversing all the centres of resistance of a series of joints; its form, in the positions intermediate between the actual joints of the structure, being determined by supposing the pieces and their loads to be subdivided by the introduction of intermediate joints *ad infinitum*, and finding the continuous line, curved or straight, in which the intermediate centres of resistance are all situated, how great soever their number. The difference between the line of resistance and the line of pressures was first pointed out by Mr Moseley.

12. *Stability of Position, and Stability of Friction.*—The resistances at the several joints having been determined by the principles set forth in sections 7, 8, 9, 10, and 11, not only under the ordinary load of the structure, but

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[1] *Mechanics of Engineering and Architecture*, by the Rev. Henry Moseley.

under all the variations to which the load is subject as to amount and distribution, the joints are now to be placed and shaped so that the pieces shall not suffer relative displacement under any of those loads. The relative displacement of the two pieces which abut against each other at a joint may take place either by turning or by sliding. Safety against displacement by turning is called *stability of position;* safety against displacement by sliding, *stability of friction.*

13. *Condition of Stability of Position.*—If the materials of a structure were infinitely stiff and strong, stability of position at any joint would be insured simply by making the centre of resistance fall within the joint under all possible variations of load. In order to allow for the finite stiffness and strength of materials, the least distance of the centre of resistance inward from the nearest edge of the joint is made to bear a definite proportion to the depth of the joint measured in the same direction, which proportion is fixed, sometimes empirically, sometimes by theoretical deduction from the laws of the strength of materials. That least distance is called by Mr Moseley the *modulus of stability.* The following are some of the ratios of the modulus of stability to the depth of the joint which occur in practice:—

Retaining walls, as designed by British engineers	$\frac{1}{8}$
Retaining walls, as designed by French engineers	$\frac{1}{5}$
Rectangular piers of bridges and other buildings, and arch-stones	$\frac{1}{3}$
Rectangular foundations, firm ground	$\frac{1}{3}$
Rectangular foundations, very soft ground	$\frac{1}{2}$
Rectangular foundations, intermediate kinds of ground	$\frac{1}{3}$ to $\frac{1}{2}$
Thin, hollow towers (such as furnace chimneys exposed to high winds), square	$\frac{1}{6}$
Thin, hollow towers, circular	$\frac{1}{4}$

(In the last two cases, the *depth of the joint* is to be understood to mean the *diameter of the tower.*)

Frames of timber or metal, under their ordinary or average distribution of load	$\frac{1}{2}$
Frames of timber or metal, under the greatest irregularities of load	$\frac{1}{3}$

14. *Condition of Stability of Friction.*—If the resistance to be exerted at a joint is always perpendicular to the surfaces which abut at and form that joint, there is no tendency of the pieces to be displaced by sliding. If the resistance be oblique, let JK (fig. 3) be the joint; C its centre of resistance; CR a line representing the resistance; CN a perpendicular to the joint at the centre of resistance. The angle NCR is the *obliquity* of the resistance. From R draw RP parallel and RQ perpendicular to the joint; then by the principles of statics, the component of the resistance *normal* to the joint is—

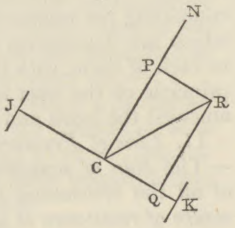


Fig. 3.

$$\overline{CP}=\overline{CR}\cdot\cos\angle PCR;$$

and the component *tangential* to the joint is—

$$\overline{CQ}=CR\cdot\sin\angle PCR=\overline{CP}\cdot\tan\angle PCR.$$

If the joint be provided either with projections and recesses, such as mortises and tenons, or with fastenings, such as pins or bolts, so as to resist displacement by sliding, the question of the utmost amount of the tangential resistance $\overline{CQ}$ which it is capable of exerting depends on the *strength* of such projections, recesses, or fastenings, and belongs to the subject of strength, and not to that of stability. In other cases the safety of the joint against displacement by sliding depends on its power of exerting friction, and that power depends on the law, known by experiment, that the friction between two surfaces bears a constant ratio, depending on the nature of the surfaces, to the force by which they are pressed together. In order that the surfaces which abut at the joint JK may be pressed together, the resistance required by the conditions of equilibrium, $\overline{CR}$, must be a *thrust* and not a *pull;* and in that case the force by which the surfaces are pressed together is equal and opposite to the normal component $\overline{CP}$ of the resistance. The condition of stability of friction is, that the tangential component $\overline{CQ}$ of the resistance required shall not exceed the friction due to the normal component; that is, that

$$\overline{CQ}\leqq f\cdot\overline{CP}$$

where f denotes the *coefficient of friction* for the surfaces in question. The angle whose tangent is the coefficient of friction is called *the angle of repose,* and is expressed symbolically by—

$$\varphi=\text{arc}\cdot\tan f.$$

$$\text{Now }\overline{CQ}=\overline{CP}\cdot\tan\angle PCR;$$

consequently the condition of stability of friction is fulfilled if

$$\angle PCR\leqq\phi;$$

that is to say, if *the obliquity of the resistance required at the joint does not exceed the angle of repose;* and this condition ought to be fulfilled under all possible variations of the load.

It is chiefly in masonry and earthwork that stability of friction is relied on.

15. *Stability of Friction in Earth.*—The grains of a mass of loose earth are to be regarded as so many separate pieces abutting against each other at joints in all possible positions, and depending for their stability on friction. To determine whether a mass of earth is stable at a given point, conceive that point to be traversed by planes in all possible positions, and determine which position gives the greatest obliquity to the total pressure exerted between the portions of the mass which abut against each other at the plane. The condition of stability is, that this obliquity shall not exceed the angle of repose of the earth. The consequences of this principle are developed in a paper "On the Stability of Loose Earth," already cited in sect. 3.

16. *Parallel Projections of Figures.*—If any figure be referred to a system of co-ordinates, rectangular or oblique; and if a second figure be constructed by means of a second system of co-ordinates, rectangular or oblique, and either agreeing with or differing from the first system in rectangularity or obliquity, but so related to the co-ordinates of the first figure that for each point in the first figure there shall be a corresponding point in the second figure, the lengths of whose co-ordinates shall bear, respectively, to the three corresponding co-ordinates of the corresponding point in the first figure, three ratios which are the same for every pair of corresponding points in the two figures; that pair of figures are called *parallel projections* of each other. The properties of parallel projections of most importance to the subject of the present article are the following:—

(1.) A parallel projection of a straight line is a straight line.

(2.) A parallel projection of a plane is a plane.

(3.) A parallel projection of a straight line or a plane surface divided in a given ratio, is a straight line or a plane surface divided in the same ratio.

(4.) A parallel projection of a pair of equal and parallel straight lines, or plain surfaces, is a pair of equal and parallel straight lines, or plane surfaces, whence it follows:—

(5.) That a parallel projection of a parallelogram is a parallelogram;—

(6.) That a parallel projection of a parallelopiped is a parallelopiped.

(7.) A parallel projection of a pair of solids having a given ratio is a pair of solids having the same ratio.

Though not essential for the purposes of the present article, the following consequence will serve to illustrate the principle of parallel projections :—

(8.) A parallel projection of a curve, or of a surface of a given algebraical order, is a curve, or a surface of the same order.

For example, all ellipsoids referred to co-ordinates parallel to any three conjugate diameters are parallel projections of each other, and of a sphere referred to rectangular co-ordinates.

17. *Parallel Projections of Systems of Forces.*—If a balanced system of forces be represented by a system of lines, then will every parallel projection of that system of lines represent a balanced system of forces.

For the condition of equilibrium of forces not parallel is, that they shall be represented in direction and magnitude by the sides and diagonals of certain parallelograms ;—and of parallel forces, that they shall divide certain straight lines in certain ratios ; and the parallel projection of a parallelogram is a parallelogram, and that of a straight line divided in a given ratio, is a straight line divided in the same ratio.

The resultant of a parallel projection of any system of forces is the projection of their resultant ; and the centre of gravity of a parallel projection of a solid is the projection of the centre of gravity of the first solid.

18. *Principle of the Transformation of Structures.*—

> Theorem.—If a structure of a given figure have stability of position under a system of forces represented by a given system of lines, then will any structure, whose figure is a parallel projection of that of the first structure, have stability of position under a system of forces represented by the corresponding projection of the first system of lines.

For in the second structure the weights, external pressures, and resistances, will balance each other as in the first structure ; the weights of the pieces, and all other parallel systems of forces, will have the same ratios as in the first structure ; and the several centres of resistance will divide the depths of the joints in the same proportions as in the first structure.

If the first structure have stability of friction, the second structure will have stability of friction also, so long as the effect of the projection is not to increase the obliquity of the resistance at any joint beyond the angle of repose.

The lines representing the forces in the second figure show their *relative* directions and magnitudes. To find their *absolute* directions and magnitudes, a vertical line is to be drawn in the first figure, of such a length as to represent the weight of a particular portion of the structure. Then will the projection of that line in the projected figure indicate the vertical direction, and represent the weight of the part of the second structure corresponding to the before-mentioned portion of the first structure.

The foregoing "principle of the transformation of structures" was first announced, though in a somewhat less comprehensive form, to the Royal Society on the 6th of March 1856. It is here published in its most general form for the first time in type, having previously appeared only in the lithographed abstract of some lectures. It is useful in practice, by enabling the engineer easily to deduce the conditions of equilibrium and stability of structures of complex and unsymmetrical figures from those of structures of simple and symmetrical figures. By its aid, for example, the whole of the properties of elliptical arches, whether square or skew, whether level or sloping in their span, are at once deduced by projection from those of symmetrical circular arches, and the properties of ellipsoidal and elliptic-conoidal domes from those of hemispherical and circular-conoidal domes ; and the figures of arches fitted to resist the thrust of earth, which is less horizontally than vertically in a certain given ratio, can be deduced by projection from those of arches fitted to resist the thrust of a liquid, which is of equal intensity, horizontally and vertically.

19. *Conditions of Stiffness and Strength.*—After the arrangement of the pieces of a structure, and the size and figure of their joints or surfaces of contact have been determined so as to fulfil the conditions of *stability*,—conditions which depend mainly on the position and direction of the *resultant* or *total* load on each piece, and the *relative* magnitude of the loads on the different pieces,—the dimensions of each piece singly have to be adjusted so as to fulfil the conditions of *stiffness* and *strength*,—conditions which depend not only on the *absolute* magnitude of the load on each piece, and of the resistances by which it is balanced, but also on the *mode of distribution* of the load over the piece, and of the resistances over the joints.

The effect of the pressures applied to a piece, consisting of the load and the supporting resistances, is to force the piece into a state of *strain* or disfigurement, which increases until the elasticity, or resistance to strain, of the material causes it to exert a *stress*, or effort to recover its figure, equal and opposite to the system of applied pressures. The condition of *stiffness* is, that the strain or disfigurement shall not be greater than is consistent with the purposes of the structure ; and the condition of *strength* is, that the stress shall be within the limits of that which the material can bear with safety against breaking. The ratio in which the utmost stress before breaking exceeds the safe working stress is called the *factor of safety*, and is determined empirically. It varies from three to twelve for various materials and structures.

The Strength of Materials forms the subject of a special article, to which the reader is now referred.

PART II.—THEORY OF MACHINES.

20.—*Parts of a Machine—Frame and Mechanism.*—The parts of a machine may be distinguished into two principal divisions,—the *frame*, or fixed parts, and the *mechanism*, or moving parts. The frame is a structure which supports the pieces of the mechanism, and to a certain extent determines the nature of their motions. The form and arrangement of the pieces of the frame depend upon the arrangement and the motions of the mechanism ; the dimensions of the pieces of the frame required in order to give it stability and strength, are determined from the pressures applied to it by means of the mechanism. It appears, therefore, that in general the mechanism is to be designed first and the frame afterwards, and that the designing of the frame is regulated by the principles of the stability of structures and of the strength and stiffness of materials ; care being taken to adapt the frame to the most severe load which can be thrown upon it at any period of the action of the mechanism.

Each independent piece of the mechanism also is a structure, and its dimensions are to be adapted, according to the principles of the strength and stiffness of materials, to the most severe load to which it can be subjected during the action of the machine.

21. *Definition and Division of the Theory of Machines.*—From what has been said in the last section, it appears that the department of the art of designing machines which has reference to the stability of the frame, and to the stiffness and strength of the frame and mechanism, is a branch of the art of construction. It is therefore to be separated from the *theory of machines*, properly speaking, which has

reference to the action of machines considered as moving. In the action of a machine the following three things take place:—

First, Some natural source of energy communicates motion and force to a piece or pieces of the mechanism, called the *receiver of power*, or *prime mover*.

Secondly, The motion and force are transmitted from the prime mover through the *train of mechanism* to the *working piece or pieces*, and during that transmission the motion and force are modified in amount and direction, so as to be rendered suitable for the purpose to which they are to be applied.

Thirdly, The working piece or pieces, by their motion, or by their motion and force combined, produce some useful effect.

Such are the phenomena of the action of a machine, arranged in the order of *causation*. But in studying or treating of the theory of machines, the order of *simplicity* is the best; and in this order the first branch of the subject is the modification of motion and force by the train of mechanism; the next is the effect or purpose of the machine; and the last, or most complex, is the action of the prime mover.

The modification of motion and the modification of force take place together, and are connected by certain laws; but in the study of the theory of machines, as well as in that of pure mechanics, much advantage has been gained in point of clearness and simplicity by first considering alone the principles of the modification of motion, which are founded upon a branch of geometry called Cinematics, and afterwards considering the principles of the combined modification of motion and force, which are founded both on geometry and on the laws of dynamics. The separation of Cinematics from Dynamics is due mainly to Monge, Ampère, and Professor Willis.

The theory of machines in the present article will be considered under the following four heads:—

I. PURE MECHANISM, or APPLIED CINEMATICS; being the theory of machines considered simply as modifying motion.
II. APPLIED DYNAMICS; being the theory of machines considered as modifying both motion and force.
III. PURPOSES AND EFFECTS OF MACHINES.
IV. APPLIED ENERGETICS; being the theory of prime movers and sources of power.

CHAP. I.—ON PURE MECHANISM.

22. *Division of the subject.*—Proceeding in the order of simplicity, the subject of Pure Mechanism, or Applied Cinematics, may be thus divided:—

Division 1. Motion of a point.
Division 2. Motion of the surface of a fluid.
Division 3. Motion of a rigid solid.
Division 4. Motions of a pair of connected pieces, or of an "*elementary combination*" in mechanism.
Division 5. Motions of *trains* of pieces of mechanism.
Division 6. Motions of sets of more than two connected pieces, or of "*aggregate combinations*."

A point is the boundary of a line, which is the boundary of a surface, which is the boundary of a volume. Points, lines, and surfaces have no independent existence, and consequently those divisions of this chapter which relate to their motions are only preliminary to the subsequent divisions, which relate to the motions of bodies.

DIVISION I.—MOTION OF A POINT.

23. *Path and Direction.*—The motion of a point is the change of its place relatively to some portion of space, which for the time is considered as fixed. In the theory of machines, the portion of space which is considered as fixed is usually that which is occupied by the frame of the machine. A moving point traces in the fixed space a line called its *path*, which may be straight or curved. The *direction* of the motion of the point at any instant is that of a tangent to the path drawn forwards from the position of the point at the instant in question, and is uniform if the path is straight—variable if it is curved.

24. *Uniform Velocity.*—The *velocity* or *speed* of a moving point is the length of the portion of its path which it traces in some given portion or unit of time. In calculations respecting dynamical questions, the unit of time commonly employed is the *second;* in considering the *purposes* of machines, the *minute*, the *hour*, and the *day* are also employed. When not otherwise specified, the *second* is the unit of time employed in this article. When a point continues always to trace equal lengths of its path in equal times, its velocity is said to be *uniform*, and is expressed numerically by dividing the length of any portion whatsoever of the path of the point by the time occupied by the point in tracing it. The unit of length employed in Britain to express velocities is usually the foot, but in some cases the mile. In the present article the foot is employed, where not otherwise specified; so that velocities will generally be stated in *feet per second.*

25. *Varied Velocity.*—When a moving point does not trace equal lengths of its path in equal times, its velocity is said to be *varied.* In this case it is no longer possible to compute the velocity simply by dividing the length traced between two given instants by the time occupied in tracing it, because such a computation gives different results for different pairs of instants: it gives, not the *exact* velocity at a particular instant, but the *mean* velocity between the pair of instants.

For example, let A, B denote a pair of instants of time, Δt the interval of time between them, Δs the length of path traced by the moving point in that interval, then is $\frac{\Delta s}{\Delta t}$ the *mean velocity* in the interval between A and B.

Now let C denote an instant of time anywhere between A and B, and let it be required to find the *exact* velocity of the moving point at the instant C. $\frac{\Delta s}{\Delta t}$ will be an *approximation* to that velocity. To find a closer approximation, take two instants A′ and B′, nearer to C than A and B are; let $\Delta t'$ be the interval of time, and $\Delta s'$ the length traced between A′ and B′; then will $\frac{\Delta s'}{\Delta t'}$ be a closer approximation than $\frac{\Delta s}{\Delta t}$. Having obtained a series of such approximations,

$$\frac{\Delta s}{\Delta t}, \frac{\Delta s'}{\Delta t'}, \frac{\Delta s''}{\Delta t''}, \text{\&c.},$$

by taking pairs of instants continually nearer and nearer to C, compare their results; it will be found that they follow some *law*, and that each of the mean velocities denoted above consists of a *constant part*, and of a *variable part* which continually diminishes and approximates to nothing as Δt grows smaller; that is to say, as A and B approximate to C. The constant part of the mean velocity, being the *limit* towards which $\frac{\Delta s}{\Delta t}$ approximates as Δt diminishes, is the *exact* velocity at the instant C, and is thus denoted,—

$$v = \frac{ds}{dt} \quad \ldots \ldots \quad (1.)$$

The process above described is well known in the differential calculus by the name of *differentiation;* that is to say, *finding the rate of variation* of one quantity s as compared with that of another quantity t.

In order to distinguish between motions in two opposite directions along the same path, one of those directions is called *forward*, and treated as *positive* in algebra; while the other is called *backward*, and treated as *negative*. Thus, let n denote a certain number of feet per second; then

$$v=\frac{ds}{dt}=n, \text{ or } +n,$$

will express that the velocity of the moving point is n feet per second *forwards;* and

$$v=\frac{ds}{dt}=-n$$

will express that the velocity is of equal magnitude, but *backward.*

26. *Direct Deviation, or Acceleration and Retardation.*—When the *motion* of a point is said to be *uniform*, without further qualification, it is to be understood to be uniform both in velocity and in direction.

The word *deviation* in its general sense denotes the amount of any departure from uniformity of motion, whether of velocity or of direction; and the *rate* at which any deviation takes place is ascertained by differentiation.

The rate of direct deviation is the rate at which the velocity varies, and is denoted by

$$\frac{dv}{dt}=\frac{d^2s}{dt^2}, \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (2.)$$

being deduced from the changes of velocity in different intervals of time in the same way that the velocity is deduced from the changes of position; that is, by differentiation. Direct deviation is *acceleration* if the velocity is increased, *retardation* if it is diminished; it is *positive* if forward velocity is increased, or backward velocity diminished; *negative* if forward velocity is diminished, or backward velocity increased.

27. *Lateral Deviation or Deflection—Angular Velocity of Deviation—Revolution.*—The rate of lateral deviation, being the rate at which the moving point swerves from a straight course, is found for any instant by multiplying the velocity of the moving point by the rate at which the angular direction of its path varies. Symbolically, let θ denote the angle (expressed in length of arc to radius unity) which at any instant the path of the point makes with some fixed direction in the plane in which, for the instant, the deflection takes place; then $\frac{d\theta}{dt}$, found as before, is the rate at which the angular direction of the path varies. Let ρ denote the *radius of curvature* of the path at the instant in question; then, by the geometry of curves, it is known that

$$\frac{d\theta}{ds}=\frac{1}{\rho};$$

consequently,

$$\frac{d\theta}{dt}=\frac{ds}{\rho dt}=\frac{v}{\rho},$$

and the *rate of lateral deviation* is expressed by

$$v\frac{d\theta}{dt}=\frac{v^2}{\rho}=\rho\left(\frac{d\theta}{dt}\right)^2 \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (3.)$$

Lateral deviation is considered as positive or negative, according to arbitrary arrangements respecting the sign of the radius of curvature of the path.

The quantity above represented by $\frac{d\theta}{dt}$ is sometimes called the *angular velocity of deviation.*

A point whose path deviates continually until it returns to its primitive direction is said to *revolve;* and the *mean angular velocity of revolution* is the circumference of a circle of the radius unity, divided by the time of one revolution.

28. *Comparative Motion.*—The comparative motion of two points is the relation which exists between their motions, without having regard to their absolute amounts. It consists of two elements,—the *velocity ratio*, which is the ratio of any two magnitudes bearing to each other the proportions of the respective velocities of the two points at a given instant; and the *directional relation*, which is the relation borne to each other by the respective directions of the motions of the two points at the same given instant.

It is obvious that the motions of a pair of points may be varied in any manner, whether by direct or by lateral deviation, and yet that their *comparative motion* may remain constant, in consequence of the deviations taking place in the same proportions, in the same directions, and at the same instants for both points.

Mr Willis has the merit of having been the first to simplify considerably the theory of pure mechanism, by pointing out that that branch of mechanics relates wholly to comparative motions.

The comparative motion of two points at a given instant is capable of being completely expressed by one of Sir William Hamilton's Quaternions,—the "Tensor" expressing the velocity-ratio, and the "Versor" the directional relation.

29. *Resolution and Composition of Motion.*—Let OPQ be part of the path of a moving point, and P the position of that point at any given instant. Let OX, OY, OZ, be any three *axes*, or fixed directions, traversing a fixed point O called the *origin.* Let three points, P_x, P_y, P_z, start from O at the same instant with P, moving respectively along the straight paths OX, OY, OZ, in such a manner that at each instant

$$OP_x=x, \qquad OP_y=y, \qquad OP_z=z,$$

shall be respectively equal to

$$PA, \qquad PB, \qquad PC,$$

the respective distances of P from the *co-ordinate planes,*

$$YOZ, \qquad ZOX, \qquad XOY,$$

measured respectively in directions parallel to the three axes,

$$OX, \qquad OY, \qquad OZ.$$

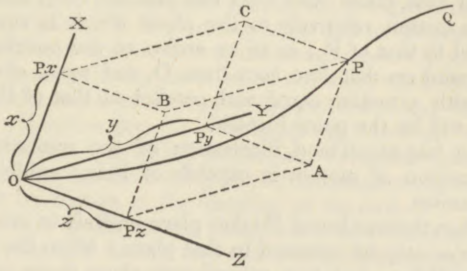


Fig. 4.

Then are P_x, P_y, P_z, called the *projections* of P on the three axes respectively; their motions are called the *components* of the motion of P parallel to the three axes; and the operation of determining those component motions is called the *resolution* of the motion of P relatively to the three axes. The operation of determining the motion of P, when its components are given, is called the *composition* of those components; and the motion of P is called the *resultant* of the motions of its projections. The following propositions are the main principles of the composition and resolution of motion:—

(1.) The straight line joining P and O is the diagonal of the parallelopiped $OP_xP_yP_zABCP$, of which x, y, z, are the edges.

(2.) If a straight line be drawn representing in direction and magnitude the velocity $v=\frac{ds}{dt}$ of P at any instant, that straight line will be the diagonal of the parallelopiped whose edges respectively represent in direction and magnitude the component velocities of P_x, P_y, and P_z; viz.,

$$\frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt}.$$

(3.) If the three respective motions of P_x, P_y, P_z, during one and the same interval of time, be determined, and if a moving point, starting from O, be made to perform in three consecutive intervals of time, motions equal and parallel to those three motions respectively, in any order of succession, then will the last-mentioned point arrive at the position occupied by P at the end of the first-mentioned interval of time.

(The path of the last-mentioned point may be any one of the six routes from O to P along the edges of the parallelopiped.)

(4.) If a plane always parallel to one of the co-ordinate planes (such as YOZ) be made to start from O at the same instant with P, and to move with the same motion as the projection of P on one of the axes (such as P_x); and if a line in that moving plane, always parallel to another of the axes (such as OZ), be made to start from O, and move *relatively* to that plane with a motion parallel and equal to that of the projection of P on the remaining axis (such as P_y); and if a point in that moving line be made to start from O, and move along that line with a motion parallel and equal to that of the third projection of P (such as P_z); then will this moving point coincide at every instant with P itself.

For example, let a plane start from the position AP_yOP_z and move along with P_x to the position PBP_xC; let a line in that plane start from the position OP_z, and move with a motion relatively to the plane which is equal and parallel to that of P_y, so as to arrive at the position CP; let a point on that line start from O, and move along the line with a motion equal and parallel to that of P_z; that point will be the point P itself.

The last-mentioned illustration of the resolution and composition of motion is capable of being exhibited by mechanism.

When the motion of P takes place entirely in one plane, two axes may be assumed in that plane; when the motion of P will have but two components along those two axes respectively, and the parallelopiped will be reduced to a parallelogram.

30. *Rectangular Projection, Resolution, and Composition.*—The choice of the three or two axes is a matter of convenience. When there is no special reason for making them oblique, they are made perpendicular to each other, or *rectangular;* and when obliquity of the axes is not specified, rectangularity is to be understood. In this case the projection of a moving point upon any one of the axes is found by letting fall a perpendicular from the point on that axis.

Let $\overline{\mathrm{OP}} = r$ denote the distance of the point from the origin at any given instant, and $\widehat{xr} = \angle \mathrm{XOP}$, the angle which that distance makes with any given axis; then for rectangular projection,

$$x = \overline{\mathrm{OP}}_x = r.\cos \widehat{xr} \quad . \quad . \quad . \quad . \quad (4.)$$

Also let v be the velocity of P at any given instant, and $\widehat{xv}$ the angle which the direction of its motion, or tangent to its path, makes at the same instant with the direction of OX; then the velocity of the rectangular projection P_x at the same instant is

$$\frac{dx}{dt} = v.\cos \widehat{xv} \quad . \quad . \quad . \quad . \quad (5.)$$

Adopting an analogous notation for other two rectangular axes, we have—

$$\left.\begin{array}{c} \cos^2 \widehat{xr} + \cos^2 \widehat{yr} + \cos^2 \widehat{zr} = 1; \\ \cos^2 \widehat{xv} + \cos^2 \widehat{yv} + \cos^2 \widehat{zv} = 1; \\ x^2 + y^2 + z^2 = r^2; \\ \left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2 = v^2. \end{array}\right\} \quad . \quad (6.)$$

31. *Resolution and Composition of Deviations.*—As the three projections of a moving point move in straight lines, their rates of deviation, if any, are wholly direct, and are represented by

$$\frac{d^2x}{dt^2}; \qquad \frac{d^2y}{dt^2}; \qquad \frac{d^2z}{dt^2}.$$

If three lines be drawn representing those three rates of deviation in direction and magnitude, the diagonal of the parallelopiped of which they are the edges is the *total* or *resultant* rate of deviation, and is the same in magnitude and direction with the diagonal of a rectangular parallelogram one of whose sides is parallel to the direction of motion of P, and represents in magnitude its rate of direct deviation $\frac{d^2s}{dt^2} = \frac{dv}{dt}$, while the other is drawn in the direction of the radius of curvature of the path of P, and represents in magnitude its rate of lateral deviation $\frac{v^3}{\rho}$. This is easily verified by the aid of well-known formulæ of the geometry of curved lines. If the motion of a point be uniform both in velocity and in direction, the components of that motion are uniform also; but if the motion of the point be deviated either in velocity or in direction, or in both, the components are deviated in velocity.

DIVISION II.—MOTION OF THE SURFACE OF A FLUID MASS.

32. *General Principle.*—A mass of fluid is used in mechanism to transmit motion and force between two or more moveable portions (called *pistons* or *plungers*) of the solid envelope or vessel in which the fluid is contained; and when such transmission is the sole action, or the only appreciable action of the fluid mass, its volume is either absolutely constant, by reason of its temperature and pressure being maintained constant, or not sensibly varied.

Let a represent the area of the section of a piston made by a plane perpendicular to its direction of motion, and v its velocity, which is to be considered as positive when outward, and negative when inward. Then the variation of the cubic contents of the vessel in a unit of time by reason of the motion of one piston is va. The condition that the volume of the fluid mass shall remain unchanged, requires that there shall be more than one piston, and that the velocities and areas of the pistons shall be connected by the equation

$$\Sigma . va = 0 \quad . \quad . \quad . \quad . \quad (7.)$$

33. *Comparative Motion of two Pistons.*—If there be but two pistons whose areas are a_1 and a_2, and their velocities v_1 and v_2, their comparative motion is expressed by the equation—

$$\frac{v_2}{v_1} = -\frac{a_1}{a_2}; \qquad . \qquad (8.)$$

that is to say, their velocities are opposite as to inwardness and outwardness, and inversely proportional to their areas.

34. *Applications: Hydraulic Press—Pneumatic Power-Transmitter.*—In the Hydraulic Press the vessel consists of two cylinders, viz., the pump-barrel and the press-barrel, each having its piston, and of a passage connecting them having a valve opening towards the press-barrel. The action of the inclosed water in transmitting motion takes place during the inward stroke of the pump-plunger, when the above-mentioned valve is open; and at that time the press-plunger moves outwards with a velocity which is less than the inward velocity of the pump-plunger, in the same ratio that the area of the pump-plunger is less than the area of the press-plunger. (For details respecting this machine, &c., see HYDRODYNAMICS.)

In the Pneumatic Power-Transmitter the motion of one piston is transmitted to another at a distance by means of a mass of air contained in two cylinders and an intervening tube. When the pressure and temperature of the air can be maintained constant, this machine fulfils equation 8, like the hydraulic press. The amount and effect of the variations of pressure and temperature undergone by the air depend on the principles of the mechanical action of heat, or *Thermodynamics*, and are foreign to the subject of pure mechanism.

DIVISION III.—MOTION OF A RIGID SOLID.

35. *Motions Classed: Shifting and Turning.*—In problems of mechanism, each solid piece of the machine is supposed to be so stiff and strong as not to undergo any sensible change of figure or dimensions by the forces applied to it; a supposition which is realized in practice if the machine is skilfully designed.

This being the case, the various possible motions of a rigid solid body may all be classed under the following heads:—

(1.) *Shifting* or *Translation*, when every point in the body has the same motion at the same instant, and when consequently no point in the body has any motion relatively to another.

(2.) *Turning* or *Rotation*, being the only kind of relative motion amongst the points of a body which is possible without change of dimensions or figure.

(3.) Motions compounded of shifting and turning.

36. *Shifting or Translation.*—In a motion of simple shifting or translation all the points of the body are moving with the same velocity, and in the same direction, at the same instant. The path of a given point may be a line of any figure—straight, curved, or angular; and the path of every other point will be a line of the same figure and dimensions. Every plane and every straight line fixed in the body moves parallel to itself.

The *relative* motion of any two points is null; that is to say, the line joining them alters neither in length nor in direction.

The *comparative* motion of any two points is expressed by the ratio of equality between their velocities, and the relation of parallelism between their directions.

The most common forms for the paths of the points of a piece of mechanism, whose motion is simple shifting, are the straight line and the circle.

Shifting in a straight line is regulated either by straight fixed guides, in contact with which the moving piece slides, or by combinations of link-work, called *parallel motions*, which will be described in the sequel. Shifting in a straight line is usually *reciprocating;* that is to say, the piece, after shifting through a certain distance, returns to its original position by reversing its motion.

Circular shifting is regulated by attaching two or more points of the shifting piece to ends of equal and parallel rotating cranks, or by combinations of wheel-work to be afterwards described. As an example of circular shifting, may be cited the motion of the coupling rod, by which the parallel and equal cranks upon two or more axles of a locomotive engine are connected and made to rotate simultaneously. The coupling rod remains always parallel to itself, and all its points describe equal and similar circles relatively to the frame of the engine, and move in parallel directions with equal velocities at the same instant.

37. *Turning or Rotation in general.*—Turning or rotation is a motion of a body such that a line fixed in or relatively to the body changes its direction. The *plane of rotation* is a plane parallel to those lines in the body whose change of direction is most rapid. As the rigidity of the body makes all lines in it preserve unchanged their directions relatively to each other, all lines in the body parallel to the plane of rotation change their direction by the same amount in the same interval of time. The *rate* of change of direction of such lines, which, if uniform, is the angle swept through by each of them in an unit of time, and, if variable, is the limit towards which that angle approximates in the operation of differentiation, is the *angular velocity of rotation* of the body, and is denoted by $\frac{d\theta}{dt}$, where θ is the angle made by a line fixed in the body with some fixed direction in the plane of rotation.

Each one of the parts of a rigid turning body, how small soever, turns in the same manner and in the same time with the whole body, and has obviously the same angular velocity of rotation with the whole body.

The *direction of the axis of rotation* is perpendicular to the plane of rotation, and is the direction of all those lines in the body whose rate of change of direction is null. This direction may either be *permanent* or *instantaneous.* It, or any line parallel to it, is sometimes called the *axis* simply; but the use of the word *axis* alone more commonly implies, in speaking of mechanism, a line in the body (such as the central line of an arbor or shaft) whose *position* as well as its direction is unchanged, either relatively to the frame (in which case it is a *fixed* axis), or relatively to some other piece of mechanism which carries the turning piece under consideration. When there is no fixed axis, the *instantaneous axis* is an ideal line, which at a given instant is at rest relatively to the turning body and to the frame.

Rotation is said to be *right-handed* relatively to an observer looking in the direction of the axis, when it is like that of the hands of a watch; *left-handed* when the contrary. Rotation may be *alternately* right and left handed, in which case it is called *oscillation.* Angular velocity of rotation may be *deviated* either by acceleration, by retardation, or by change in the direction of the axis.

38. *Relative Motions of Two Points in a Turning Body.*—Let A and B denote any two points in a turning body, and let it be required to express the motion of B relatively to A. Through A draw a line AO in the direction of the axis, on which let fall a perpendicular from B; let r denote the length of that perpendicular. Then is the motion of B relatively to A a translation in a circular path of the radius r about the axis AO; the *angular velocity of deviation* of B is the same with the angular velocity of rotation of the body $\frac{d\theta}{dt}$, and the linear velocity of B relatively to A is $r\frac{d\theta}{dt}$, in a direction perpendicular to the plane AOB.

The motion of A relatively to B is exactly the same with that of B relatively to A.

39. *Comparative Motion of Two Points relatively to a Third.*—If there be a point C at the perpendicular distance r' from AO, the velocity of that point in its motion relatively to A will be $r'\frac{d\theta}{dt}$; and the *comparative motion* of B and C relatively to A will be expressed by the ratio $r : r'$ between their velocities, and by the angle $\overset{\wedge}{r\,r'}$ between their directions of motion, being the same with the angle between the planes AOB and AOC. Thus that comparative motion is independent of the angular velocity of the turning body.

40. *Rotation about a Fixed Axis—Lever, Wheel, and Axle.*—The fixed axis of a turning body is a line fixed relatively to the body and relatively to the fixed space in which the body turns. In mechanism it is usually the central line either of a rotating shaft or axle having journals, gudgeons, or pivots turning in fixed bearings, or of a fixed spindle or dead centre round which a rotating bush turns; but it may sometimes be entirely beyond the limits of the turning body. For example, if a sliding piece moves in circular fixed guides, that piece rotates about an ideal fixed axis traversing the centre of those guides.

Let the angular velocity of the rotation be denoted by

$\alpha=\frac{d\theta}{dt}$, then the linear velocity of any point A at the distance r from the axis is αr; and the path of that point is a circle of the radius r described about the axis.

If the directions of motion of any two points A and B in the rotating body, at any one instant, be given, the axis may be determined by its being the line of intersection of two planes drawn through A and B, and perpendicular to the respective directions of motion of those points.

The *comparative motion* of A and B is expressed, like that of B and C in sec. 39, by a constant *velocity-ratio*, which is that of their perpendicular distances from the axis, and a constant *directional relation*, which is an angle equal to the angle between the two planes traversing the axis and the two points respectively. This is the principle of the modification of motion by the LEVER, which consists of a rigid body turning about a fixed axis called a fulcrum, and having two points at the same or different distances from that axis, and in the same or different directions, one of which receives motion and the other transmits motion, modified in direction and velocity according to the above law.

In the WHEEL AND AXLE motion is received and transmitted by two cylindrical surfaces of different radii described about their common fixed axis of turning, their velocity-ratio being that of their radii.

41. *Velocity-ratio of Components of Motion.*—As the distance between any two points in a rigid body is invariable, the projections of their velocities upon the line joining them must be equal. Hence it follows, that if A in fig. 5 be a point in a rigid body CD, rotating round the fixed axis F, the component of the velocity of A in any direction AP parallel to the plane of rotation, is equal to the total velocity of the point m, found by letting fall Fm perpendicular to AP; that is to say, is equal to

$$\alpha\cdot\overline{\mathrm{F}m}.$$

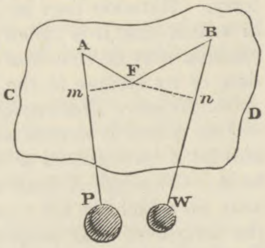


Fig. 5.

Hence also the ratio of the components of the velocities of two points A and B in the directions AP and BW respectively, both in the plane of rotation, is equal to the ratio of the perpendiculars $\overline{\mathrm{F}m}$ and $\overline{\mathrm{F}n}$.

42. *Instantaneous Axis of a Cylinder rolling on a Cylinder.*—Let a cylinder *bbb*, whose axis of figure is B, and angular velocity γ, roll on a fixed cylinder *aaa*, whose axis of figure is A, either outside (as in fig. 6), when the rolling will be towards the same hand with the rotation, or inside (as in fig. 7), when the rolling will be towards the opposite hand; and at a given instant let T be the line of contact of the two cylindrical surfaces, which is at their common intersection with the plane AB traversing the two axes of figure.

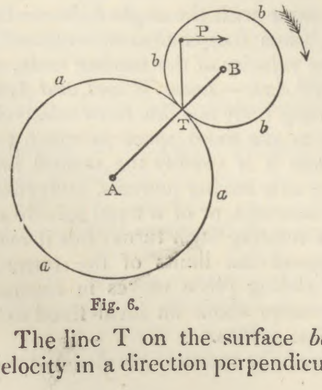


Fig. 6.

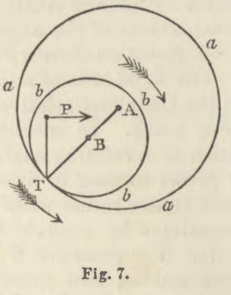


Fig. 7.

The line T on the surface *bbb* has for the instant no velocity in a direction perpendicular to AB; because for the instant it touches, without sliding, the line T on the fixed surface *aaa*.

The line T on the surface *bbb* has also for the instant no velocity in the plane AB; for it has just ceased to move towards the fixed surface *aaa*, and is just about to begin to move away from that surface.

The line of contact T, therefore, on the surface of the cylinder *bbb*, is *for the instant* at rest, and is the *instantaneous axis* about which the cylinder *bbb* turns, together with any body rigidly attached to that cylinder.

To find, then, the direction and velocity at the given instant of any point P, either in or rigidly attached to the rolling cylinder T, draw the plane PT; the direction of motion of P will be perpendicular to that plane, and towards the right or left hand according to the direction of the rotation of *bbb*; and the velocity of P will be

$$v_{\mathrm{P}}=\gamma\cdot\overline{\mathrm{PT}}; \quad .\ .\ .\ .\ .\ (9.)$$

$\overline{\mathrm{PT}}$ denoting the perpendicular distance of P from T. The path of P is a curve of the kind called *epitrochoids*. If P is in the circumference of *bbb*, that path becomes an *epicycloid.*

The velocity of any point in the axis of figure B is

$$v_{\mathrm{B}}=\gamma\cdot\overline{\mathrm{TB}}; \quad .\ .\ .\ .\ (10.)$$

and the path of such a point is a circle described about A with the radius $\overline{\mathrm{AB}}$, being for outside rolling the sum, and for inside rolling the difference, of the radii of the cylinders.

Let α denote the angular velocity with which the *plane of axes* AB rotates about the fixed axis A. Then it is evident that

$$v_{\mathrm{B}}=\alpha\cdot\overline{\mathrm{AB}} \quad .\ .\ .\ .\ .\ (11.)$$

and consequently that $\alpha=\gamma\cdot\frac{\overline{\mathrm{TB}}}{\overline{\mathrm{AB}}}$ . . . . . (12.)

For internal rolling, as in fig. 7, AB is to be treated as negative, which will give a negative value to α, indicating that in this case the rotation of AB round A is contrary to that of the cylinder *bbb*.

The angular velocity of the rolling cylinder, *relatively to the plane of axes* AB, is obviously given by the equation—

$$\left.\begin{array}{r}\beta=\gamma-\alpha;\\ \text{whence } \beta=\gamma\cdot\frac{\overline{\mathrm{TA}}}{\overline{\mathrm{AB}}};\end{array}\right\} \quad .\ .\ .\ .\ (13.)$$

care being taken to attend to the sign of α, so that when that is negative the arithmetical values of γ and α are to be added in order to give that of β.

The whole of the foregoing reasonings are applicable, not merely when *aaa* and *bbb* are actual cylinders, but also when they are the osculating cylinders of a pair of cylindroidal surfaces of varying curvature, A and B being the axes of curvature of the parts of those surfaces which are in contact for the instant under consideration.

43. *Composition and Resolution of Rotations about Parallel Axes.*—The plane AB may be considered as an arm rotating about the fixed axis A with the angular velocity α, and *carrying* the moving axis B, round which a body *bbb* rotates with the angular velocity β *relatively* to the plane or arm AB; so that the actual rotation of *bbb* about the instantaneous axis T, with a total or actual angular velocity γ, is the *resultant* of the two *component rotations* about A and B respectively.

The relations between the angular velocities of the component and resultant rotations, and the distances between their axes, are expressed by the following proportions deduced from equations 12 and 13:—

$$\left.\begin{array}{l} \alpha : \beta : \gamma \\ :: \overline{\mathrm{TB}} : \overline{\mathrm{TA}} : \overline{\mathrm{AB}} \end{array}\right\} \quad . \; . \; . \; . \quad (14.)$$

or in words as follows:—*The angular velocity of the rotation resulting from the composition of two rotations about parallel axes, is the sum of the component angular velocities if they are in the same direction, and their difference if they are contrary: the axis of the resultant rotation lies in the plane of and parallel to the axes of the component rotations—between them if they are in the same direction, beyond them if they are contrary; and its respective distances from these two axes are inversely as the angular velocities of the respective component rotations round them.*

44. *Composition of a Rotation with a Translation in the same Plane.*—The motion of the body *bbb*, and of any body attached to it, may also be regarded as compounded of the rotation, with the total angular velocity γ, about the moving axis B, and a *translation* of that axis, carrying the body along with it, in a direction perpendicular to BA with the velocity v_{B}. Hence is deduced the following rule for finding the motion resulting from the combination of a rotation, with a given total angular velocity γ, about a moving axis B, and a translation in a given direction perpendicular to B with the velocity v_{B}:—

Draw BA perpendicular to the direction of translation, and deviating from that direction to that side towards which the rotation takes place. In BA take

$$\overline{\mathrm{BT}} = \frac{v_{\mathrm{B}}}{\gamma}; \quad . \; . \; . \; . \; . \; . \quad (15.)$$

then the *instantaneous axis* for the instant under consideration is a line drawn through T parallel to B; so that the motion of any point P, in or attached to the body, is for the instant perpendicular to PT, with the velocity

$$v_{\mathrm{P}} = \gamma \cdot \overline{\mathrm{TP}} \quad . \; . \; . \; . \; . \; . \quad (16.)$$

45. *Instantaneous Axis of a Cone rolling on a Cone.*—Let O*aa* (fig. 8) be a fixed cone, OA its axis, O*bb* a cone rolling on it, OB the axis of the rolling cone, OT the line of contact of the two cones at the instant under consideration. By reasoning similar to that of sec. 42, it appears that OT is the instantaneous axis of rotation of the rolling cone.

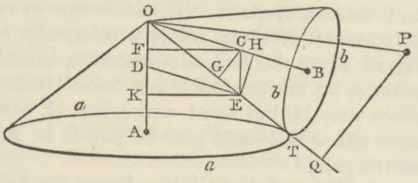


Fig. 8.

Let γ denote the total angular velocity of the rotation of the cone B about the instantaneous axis, β its angular velocity about the axis OB *relatively* to the plane AOB, and α the angular velocity with which the plane AOB turns round the axis OA.

It is required to find the ratios of those angular velocities.

Solution. In OT take any point E, from which draw EC parallel to OA, and ED parallel to OB, so as to construct the parallelogram OCED. Then

$$\left.\begin{array}{l} \overline{\mathrm{OD}} : \overline{\mathrm{OC}} : \overline{\mathrm{OE}} \\ :: \; \alpha \; : \; \beta \; : \; \gamma \end{array}\right\} \quad . \; . \; . \; . \quad (17.)$$

Or because of the proportionality of the sides of triangles to the sines of the opposite angles,

$$\left.\begin{array}{l} \sin \angle \mathrm{TOB} : \sin \angle \mathrm{TOA} : \sin \angle \mathrm{AOB} \\ :: \qquad \alpha \quad : \qquad \beta \quad : \qquad \gamma \end{array}\right\} \; . \quad (17, \mathrm{A.})$$

that is to say, the angular velocity about each axis is proportional to the sine of the angle between the other two.

Demonstration.—From C draw CF ⊥ OA, and CG ⊥ OE.

$$\text{Then } \overline{\mathrm{CF}} = 2 \times \frac{\text{area ECO}}{\mathrm{CE}},$$

$$\text{and } \overline{\mathrm{CG}} = 2 \times \frac{\text{area ECO}}{\mathrm{OE}},$$

$$\therefore \overline{\mathrm{CG}} : \overline{\mathrm{CF}} :: \overline{\mathrm{CE}} = \overline{\mathrm{OD}} : \overline{\mathrm{OE}}.$$

Let v_{C} denote the linear velocity of the point C. Then

$$v_{\mathrm{C}} = \alpha \cdot \overline{\mathrm{CF}} = \gamma \cdot \overline{\mathrm{CG}}$$

$$\therefore \gamma : \alpha :: \overline{\mathrm{CF}} : \overline{\mathrm{CG}} :: \overline{\mathrm{OE}} : \mathrm{OD};$$

which is one part of the solution above stated. From E draw EH ⊥ OB, and EK ⊥ OA. Then it can be shown as before that

$$\overline{\mathrm{EK}} : \overline{\mathrm{EH}} :: \overline{\mathrm{OC}} : \overline{\mathrm{OD}}.$$

Let v_{E} be the linear velocity of the point E *fixed in the plane of axes* AOB. Then

$$v_{\mathrm{E}} = \alpha \cdot \overline{\mathrm{EK}}.$$

Now as the line of contact OT is for the instant at rest on the rolling cone as well as on the fixed cone, the linear velocity of the point E fixed to the plane AOB relatively to the rolling cone, is the same with its velocity relatively to the fixed cone. That is to say,

$$\beta \cdot \overline{\mathrm{EH}} = v_{\mathrm{E}} = \alpha \cdot \overline{\mathrm{EK}}$$

$$\therefore \alpha : \beta :: \overline{\mathrm{EH}} : \overline{\mathrm{EK}} :: \overline{\mathrm{OD}} : \overline{\mathrm{OC}},$$

which is the remainder of the solution. Q.E.D.

The path of a point P in or attached to the rolling cone is a spherical epitrochoid traced on the surface of a sphere of the radius $\overline{\mathrm{OP}}$. From P draw PQ perpendicular to the instantaneous axis. Then the motion of P is perpendicular to the plane OPQ, and its velocity is

$$v_{\mathrm{P}} = \gamma \cdot \overline{\mathrm{PQ}} \quad . \; . \; . \; . \; . \; . \quad (18.)$$

The whole of the foregoing reasonings are applicable, not merely when A and B are actual regular cones, but also when they are the osculating regular cones of a pair of irregular conical surfaces, having a common apex at O.

46. *Composition of Rotations about Two Axes meeting in a Point.*—The plane AOB, carrying the moving axis OB, rotates about the fixed axis OA with an angular velocity α, to which $\overline{\mathrm{OD}}$ is proportioned; the cone B, or any other body, rotates about the moving axis OB with an angular velocity β, to which $\overline{\mathrm{OC}}$ is proportional; then the resultant angular velocity γ of the body B is proportional to, and the direction of the resultant rotation coincides with, the diagonal $\overline{\mathrm{OE}}$ of the parallelogram OCED.

In drawing lines, such as OC, OD, and OE, to represent in direction the axes, and in magnitude the angular velocities, of rotations, care is to be taken to make each line point from the origin O in such a direction that each rotation, looked at *from* the quarter towards which the line denoting it points, shall be of the same kind with all the rest, viz., right-handed or left-handed. Right-handed rotation is usually selected in applying this rule.

47. *Screw-like or Helical Motion.*—As it has been shown in section 44 that the combination of a rotation round a given axis, with a translation of that axis in a path parallel to the plane of rotation, is equivalent simply to a rotation round a different axis, it follows that every possible movement of a rigid body parallel to one plane is either a translation or a rotation; and that the only combination of translation and rotation, in which a complex movement which is not a mere rotation is produced, occurs when the translation is *perpendicular to the plane and parallel to the axis* of rotation.

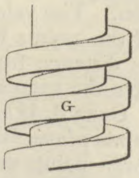


Fig. 9.

Such a complex motion is called *screw-like* or *helical* motion; for each point in the body describes a *helix* or *screw* round the axis of rotation, fixed or instantaneous as the case may be. To cause a body to move in this manner it is usually made of a helical or screw-like figure, and moves in a guide of a corresponding figure. Helical motion and screws adapted to it are said to be right or left-handed according to the appearance presented by the rotation to an observer looking towards the direction of the translation. Thus the screw G in fig. 9 is right-handed.

The translation of a body in helical motion is called its *advance*. Let v_x denote the velocity of advance at a given instant, which of course is common to all the particles of the body; a the angular velocity of the rotation at the same instant; $2\pi=6{\cdot}2832$ nearly, the circumference of a circle of the radius unity. Then

$$T=\frac{2\pi}{a} \quad . \; . \; . \; . \; . \; . \; . \quad (19.)$$

is the time of one turn at the rate a; and

$$p=v_x T=\frac{2\pi v_x}{a} \quad . \; . \; . \; . \quad (20.)$$

is the *pitch* or *advance per turn*; a length which expresses the *comparative motion* of the translation and the rotation.

The pitch of a screw is the distance, measured parallel to its axis, between two successive turns of the same *thread* or helical projection.

Let r denote the perpendicular distance of a point in a body moving helically from the axis. Then

$$v_r=ar, \quad . \; . \; . \; . \; . \; . \; . \quad (21.)$$

is the component of the velocity of that point in a plane perpendicular to the axis, and its total velocity is

$$v=\surd\{v_x^2+v_r^2\} \quad . \; . \; . \; . \quad (22.)$$

The ratio of the two components of that velocity is

$$\frac{v_x}{v_x}=\frac{p}{2\pi r}=\tan\theta; \quad . \; . \; . \; . \quad (23.)$$

where θ denotes the angle made by the helical path of the point with a plane perpendicular to the axis.

48. *To find the Motion of a Rigid Body from the Motions of Three Points in it.*—When the directions and velocities of the motions of any three points in a rigid body, not being in the same straight line, are given, the motion of the whole body is determined, and may be found.

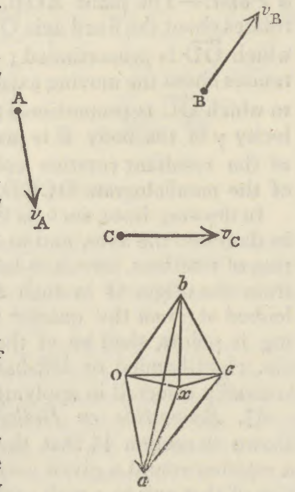


Fig. 10.

CASE 1. *When the velocities of the three points are equal and parallel*, the motion of the whole body is an equal and parallel translation.

CASE 2. *When the three points are in one plane, and their velocities are perpendicular to that plane and unequal.*—Draw three lines from the three points representing in length and direction their velocities. Through the extremities of those lines, draw a plane which will intersect the plane of the three points in the axis of rotation. The velocity of any one of the points being divided by its distance from that axis will give the angular velocity.

CASE 3. *When the motions of the three points are parallel to one plane, but not to each other.*—Through any two of the three points draw planes perpendicular to their directions of motion; those planes will cut each other in the axis of rotation; and the angular velocity may be found as in Case 2.

CASE 4. *In every other case* the motion is helical.—Let A, B, C (fig. 10) be the three points, and let the lines v_A, v_B, v_C, represent their velocities. Through any point O draw

$$Oa = \text{and} \parallel \text{to } v_A,\; Ob = \text{and} \parallel v_B,\; Oc = \text{and} \parallel v_C.$$

Through a, b, and c, draw a plane, on which let fall the perpendicular Ox. This will represent the velocity of *translation or advance*. Join xa, xb, xc; these lines will represent in direction and magnitude the components of the velocities of A, B, C, respectively, parallel to the plane of rotation. Through any two of the three points draw planes perpendicular respectively to these rotatory components of their velocities; those planes will intersect in the axis of rotation. Find the angular velocity as before.

DIVISION IV.—ELEMENTARY COMBINATIONS IN MECHANISM.

49. *Definitions.*—An *elementary combination* in mechanism consists of two pieces whose kinds of motion are determined by their connection with the frame, and their comparative motion by their connection with each other; that connection being effected either by direct contact of the pieces, or by a connecting piece, which is not connected with the frame, and whose motion depends entirely on the motions of the pieces which it connects.

The piece whose motion is the cause is called the *driver*; the piece whose motion is the effect, the *follower*.

The connection of each of those two pieces with the frame is in general such as to determine the path of every point in it. In the investigation, therefore, of the comparative motion of the driver and follower, in an elementary combination, it is unnecessary to consider relations of angular direction, which are already fixed by the connection of each piece with the frame; so that the inquiry is confined to the determination of the velocity-ratio, and of the directional-relation, so far only as it expresses the connection between *forward* and *backward* movements of the driver and follower. When a continuous motion of the driver produces a continuous motion of the follower, forward or backward, and a reciprocating motion a motion reciprocating at the same instant, the directional-relation is said to be *constant*. When a continuous motion produces a reciprocating motion, or *vice versa*; or when a reciprocating motion produces a motion not reciprocating at the same instant, the directional-relation is said to be *variable*.

The *line of action* or *of connection* of the driver and follower is a line traversing a pair of points in the driver and follower respectively, which are so connected that the component of their velocity relatively to each other, resolved along the line of connection, is null. There may be several, or an indefinite number of lines of connection, or there may be but one; and a line of connection may connect either the same pair of points or a succession of different pairs.

50. *General Principle.*—From the definition of a line of connection it follows, that *the components of the velocities of a pair of connected points along their line of connection are equal.* And from this, and from the property of a rigid body, already stated in sect. 41, it follows, that *the components, along a line of connection, of all the points traversed by that line, whether in the driver or in the follower, are equal;* and consequently, *that the velocities of any pair of points, traversed by a line of connection, are to each other inversely as the cosines, or directly as the secants, of the angles made by the paths of those points with the line of connection.*

The general principle, stated above in different forms, serves to solve every problem in which—the mode of connection of a pair of pieces being given—it is required to find their comparative motion at a given instant, or *vice versa.*

51. *Application to a Pair of Shifting Pieces.*—In fig. 11, let P_1P_2 be the line of connection of a pair of pieces, each of which has a motion of translation or shifting. Through any point T in that line draw TV_1, TV_2, respectively parallel to the simultaneous direction of motion of the pieces; through any other point A in the line of connection draw a plane perpendicular to that line, cutting TV_1, TV_2, in V_1, V_2; then,

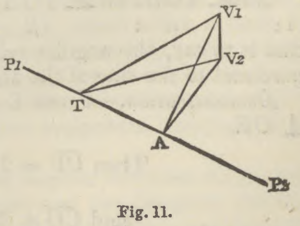


Fig. 11.

velocity of piece 1 : velocity of piece 2 : : $\overline{\mathrm{TV}_1} : \overline{\mathrm{TV}_2}$. Also, TA represents the equal components of the velocities of the pieces parallel to their line of connection, and the line $\overline{\mathrm{V}_1\mathrm{V}_2}$ represents their velocity relatively to each other.

52. *Application to a Pair of Turning Pieces.*—Let α_1, α_2 be the angular velocities of a pair of turning pieces; θ_1, θ_2, the angles which their line of connection makes with their respective planes of rotation; r_1, r_2, the common perpendiculars let fall from the line of connection upon the respective axes of rotation of the pieces. Then the equal components, along the line of connection, of the velocities of the points where those perpendiculars meet that line, are,—

$$\alpha_1 r_1 \cdot \cos\theta_1 = \alpha_2 r_2 \cdot \cos\theta_2;$$

consequently, the comparative motion of the pieces is given by the equation

$$\frac{\alpha_2}{\alpha_1} = \frac{r_1 \cdot \cos\theta_1}{r_2 \cdot \cos\theta_2}. \quad . \quad . \quad . \quad . \quad (24.)$$

53. *Application to a Shifting Piece and a Turning Piece.*—Let a shifting piece be connected with a turning piece, and at a given instant let α_1 be the angular velocity of the turning piece, r_1 the common perpendicular of its axis of rotation and the line of connection, θ_1 the angle made by the line of connection with the plane of rotation, θ_2 the angle made by the line of connection with the direction of motion of the shifting piece, v_2 the linear velocity of that piece. Then

$$\alpha_1 r_1 \cdot \cos\theta_1 = v_2 \cdot \cos\theta_2; \quad . \quad . \quad (25.)$$

which equation expresses the comparative motion of the two pieces.

54. *Classification of Elementary Combinations in Mechanism.*—The first systematic classification of elementary combinations in mechanism was that founded by Monge, and fully developed by Lanz and Bétancourt, which has been generally received, and has been adopted in most treatises on applied mechanics. But that classification is founded on the absolute, instead of the comparative motions of the pieces, and is, for that reason, defective, as Mr Willis has pointed out in his admirable treatise *On the Principles of Mechanism.*

The classification of Mr Willis is founded, in the first place, on comparative motion, as expressed by velocity-ratio and directional-relation; and, in the second place, on the mode of connection of the driver and follower. He divides the elementary combinations in mechanism into three classes, of which the characters are as follows:—

Class A: Directional-relation constant; velocity-ratio constant.

Class B: Directional-relation constant; velocity-ratio varying.

Class C: Directional-relation changing periodically; velocity-ratio constant or varying.

Each of those classes is subdivided by Mr Willis into five divisions, of which the characters are as follows:—

Division A: connection by rolling contact.
... B: ... sliding contact.
... C: ... wrapping connectors.
... D: ... link-work.
... E: ... reduplication.

In the present article the principle of the classification of Mr Willis is followed; but the arrangement is modified by taking the *mode of connection* as the basis of the primary classification, and by removing the subject of connection by reduplication to the section of aggregate combinations. This modified arrangement is adopted as being better suited than the original arrangement to the limits of an article in an Encyclopædia; but it is not disputed that the original arrangement may be the best for a separate treatise.

55. *Rolling Contact—Smooth Wheels and Racks.*—In order that two pieces may move in *rolling contact,* it is necessary that each pair of points in the two pieces which touch each other should at the instant of contact be moving in the same direction with the same velocity. In the case of two *shifting* pieces this would involve equal and parallel velocities for all the points of each piece, so that there could be no rolling, and, in fact, the two pieces would move like one; hence, in the case of rolling contact, either one or both of the pieces must rotate.

The direction of motion of a point in a turning piece being perpendicular to a plane passing through its axis, the condition, that each pair of points in contact with each other must move in the same direction, leads to the following consequences:—

I. That when both pieces rotate, their axes, and all their points of contact, lie in the same plane.

II. That when one piece rotates and the other shifts, the axis of the rotating piece, and all the points of contact, lie in a plane perpendicular to the direction of motion of the shifting piece.

The condition, that the velocities of each pair of points of contact must be equal, leads to the following consequences:—

III. That the angular velocities of a pair of turning pieces in rolling contact must be inversely as the perpendicular distances of any pair of points of contact from the respective axes.

IV. That the linear velocity of a shifting piece in rolling contact with a turning piece is equal to the product of the angular velocity of the turning piece, by the perpendicular distance from its axis to a pair of points of contact.

The *line of contact* is that line in which the points of contact are all situated. Respecting this line, the above principles III. and IV. lead to the following conclusions:—

V. That for a pair of turning pieces with parallel axes, and for a turning piece and a shifting piece, the line of contact is straight, and parallel to the axes or axis; and hence that the rolling surfaces are either plane or cylindrical (the term "cylindrical" including all surfaces generated by the motion of a straight line parallel to itself).

VI. That for a pair of turning pieces, with intersecting axes, the line of contact is also straight, and traverses the point of intersection of the axes; and hence that the rolling surfaces are conical, with a common apex (the term "conical" including all surfaces generated by the motion of a straight line which traverses a fixed point).

Turning pieces in rolling contact are called *smooth,* or *toothless wheels.* Shifting pieces in rolling contact with turning pieces may be called *smooth* or *toothless racks.*

VII. In a pair of pieces in rolling contact every straight line traversing the line of contact is a line of connection.

56. *Cylindrical Wheels and Smooth Racks.*—In designing cylindrical wheels and smooth racks, and determining their comparative motion, it is sufficient to consider a section of the pair of pieces made by a plane perpendicular to the axis or axes.

The points where axes intersect the plane of section are called *centres;* the point where the line of contact intersects it, the *point of contact,* or *pitch-point;* and the wheels are described as *circular, elliptical,* &c., according to the forms of their sections made by that plane.

When the point of contact of two wheels lies between their centres, they are said to be in *outside gearing;* when beyond their centres, in *inside gearing;* because the rolling surface of the larger wheel must in this case be turned inwards, or towards its centre.

From principle III. of sect. 55 it appears, that the angular velocity-ratio of a pair of wheels is the inverse ratio of the distances of the point of contact from the centres respectively.

For outside gearing that ratio is *negative,* because the wheels turn contrary ways; for inside gearing it is *positive*, because they turn the same way.

If the velocity-ratio is to be constant, as in Mr Willis's Class A, the wheels must be circular; and this is the most common form for wheels.

If the velocity-ratio is to be variable, as in Mr Willis's Class B, the figures of the wheels are a pair of *rolling curves*, subject to the condition that the distance between their *poles* (which are the centres of rotation) shall be constant.

The following is the geometrical relation which must exist between such a pair of curves. (See fig. 12.)

Let C_1, C_2 be the poles of a pair of rolling curves; T_1, T_2 any pair of points of contact; U_1, U_2 any other pair of points of contact. Then, for every possible pair of points of contact, the two following equations must be simultaneously fulfilled:—

$$\text{Sum of radii, } \overline{C_1U_1}+\overline{C_2U_2}=\overline{C_1T_1}+\overline{C_2T_2}=\text{constant};$$
$$\text{arc, } \overline{T_2U_2}=\overline{T_1U_1} \quad . \quad . \quad . \qquad (26.)$$

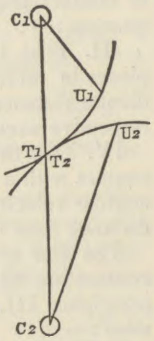


Fig. 12.

A condition equivalent to the above, and necessarily connected with it, is, that at each pair of points of contact the inclinations of the curves to their radii-vectores shall be equal and contrary; or, denoting by r_1, r_2 the radii-vectores at any given pair of points of contact, and s the length of the equal arcs measured from a certain fixed pair of points of contact—

$$\frac{dr_2}{ds}=-\frac{dr_1}{ds}; \quad . \quad . \qquad (27.)$$

which is the differential equation of a pair of rolling curves whose poles are at a constant distance apart.

[For full details as to rolling curves, see Mr Willis's work, already mentioned, and Mr Clerk Maxwell's paper on Rolling Curves in the *Transactions of the Royal Society of Edinburgh.*]

A rack, to work with a circular wheel, must be straight. To work with a wheel of any other figure, its section must be a rolling curve, subject to the condition, that the perpendicular distance from the pole or centre of the wheel to a straight line parallel to the direction of the motion of the rack shall be constant. Let r_1 be the radius-vector of a point of contact on the wheel, x_2 the ordinate from the straight line before mentioned to the corresponding point of contact on the rack. Then

$$\frac{dx_2}{ds}=\frac{dr_1}{ds} \quad . \quad . \quad . \quad . \qquad (28.)$$

is the differential equation of the pair of rolling curves.

To illustrate this subject, it may be mentioned that an ellipse rotating about one focus rolls completely round in outside gearing, with an equal and similar ellipse also rotating about one focus, the distance between the axes of rotation being equal to the major axis of the ellipses, and the velocity-ratio varying from $\frac{1+\text{eccentricity}}{1-\text{eccentricity}}$ to $\frac{1-\text{eccentricity}}{1+\text{eccentricity}}$; a hyperbola rotating about its further focus rolls, in inside gearing, through a limited arc, with an equal and similar hyperbola rotating about its nearer focus, the distance between the axes of rotation being equal to the axis of the hyperbolas, and the velocity-ratio varying between $\frac{\text{eccentricity}+1}{\text{eccentricity}-1}$ and unity; and a parabola rotating about its focus rolls with an equal and similar parabola, shifting parallel to its directrix.

57. *Conical or Bevel, and Disc Wheels.*—From principles III. and VI. of sect. 55 it appears, that the angular velocities of a pair of wheels whose axes meet in a point, are to each other inversely as the sines of the angles which the axes of the wheels make with the line of contact. Hence follows the following construction (figs. 13 and 14).—Let O be the apex or point of meeting of the two axes OC_1, OC_2. The angular-velocity-ratio being given, it is required to find the line *of contact.* On OC_1, OC_2 take lengths $\overline{OA_1}$, $\overline{OA_2}$, respectively proportional to the angular velocities of the pieces on whose axes they are taken. Complete the parallelogram OA_1EA_2; the diagonal OET will be the line of contact required.

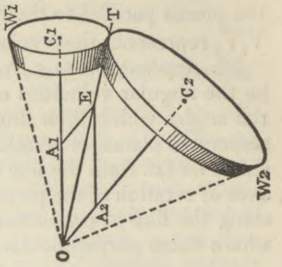


Fig. 13.

When the velocity-ratio is variable, the line of contact will shift its position in the plane C_1OC_2, and the wheels will be cones, with eccentric or irregular bases. In every case which occurs in practice, however, the velocity-ratio is constant; the line of contact is constant in position, and the rolling surfaces of the wheels are regular circular cones (when they are called *bevel wheels*); or one of a pair of wheels may have a flat disc for its rolling surface, as W_2 in fig. 14, in which case it is a *disc wheel.* The rolling surfaces of actual wheels consist of frusta or zones of the complete cones or discs, as shown by W_1, W_2, in figs. 13 and 14.

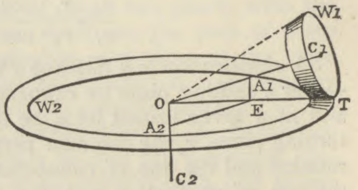


Fig. 14.

58. *Sliding Contact—lateral: Skew-Bevel Wheels.*—A hyperboloid of revolution is a surface resembling a sheaf or a dice box, generated by the rotation of a straight line round an axis from which it is at a constant distance, and to which it is inclined at a constant angle. If two such hyperboloids, equal or unequal, be placed in the closest possible contact, as in fig. 15, they will touch each other along one of the generating straight lines of each, which will form their line of contact, and will be inclined to the axes AG, BH in opposite directions. The axes will neither be parallel nor will they intersect each other.

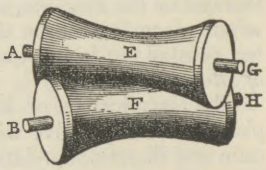
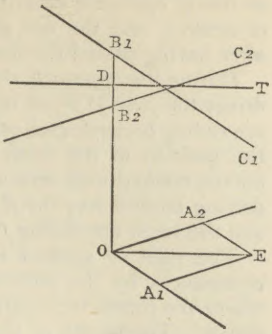


Fig. 15.

The motion of two such hyperboloids, turning in contact with each other, has hitherto been classed amongst cases of rolling contact; but that classification is not strictly correct: for although the component velocities of a pair of points of contact in a direction at right angles to the line of contact are equal, still, as the axes are neither parallel to each other nor to the line of contact, the velocities of a pair of points of contact have components along the line of contact which are unequal, and their difference constitutes a *lateral sliding.*

The directions and positions of the axes being given, and the required angular-velocity-ratio, the following construction serves to determine the line of contact, by whose rotation round the two axes respectively the hyperboloids are generated:—

In fig. 16, let B_1C_1, B_2C_2 be the two axes; B_1B_2 their common perpendicular. Through any point O in this common perpendicular draw OA_1 parallel to B_1C_1, OA_2 parallel to B_2C_2; make those lines proportional to the angular velocities about the axes to which they are respectively parallel; complete the parallelogram OA_1EA_2, and draw the diagonal OE; divide B_1B_2 in D into two parts, *inversely* proportional to the angular velocities about the axes which they respectively adjoin; through D parallel to OE draw DT. This will be the line of contact.



Fig, 16.

A pair of thin frusta of a pair of hyperboloids are used in practice to communicate motion between a pair of axes neither parallel nor intersecting, and are called *skew-bevel wheels.*

In skew-bevel wheels, the properties of a line of connection are not possessed by every line traversing the line of contact, but only by every line traversing the line of contact at right angles.

If the velocity-ratio to be communicated were variable, the point D would alter its position, and the line DT its direction, at different periods of the motion, and the wheels would be hyperboloids of an eccentric or irregular cross section; but forms of this kind are not used in practice.

59. *Sliding Contact—circular: Grooved Wheels.*—As the adhesion or friction between a pair of smooth wheels is seldom sufficient to prevent their slipping on each other, contrivances are used to increase their mutual hold. One of those consists in forming the rim of each wheel into a series of alternate ridges and grooves parallel to the plane of rotation; it is applicable to cylindrical and bevel wheels, but not to skew-bevel wheels. The comparative motion of a pair of wheels so ridged and grooved is the same with that of a pair of smooth wheels in rolling contact, whose cylindrical or conical surfaces lie midway between the tops of the ridges and bottoms of the grooves, and those ideal smooth surfaces are called the *pitch surfaces* of the wheels.

The relative motion of the faces of contact of the ridges and grooves is a *rotatory sliding*, or *grinding* motion, about the line of contact of the pitch-surfaces as an instantaneous axis.

Grooved wheels have hitherto been but little used.

60. *Sliding Contact—direct: Teeth of Wheels, Number and Pitch.*—The ordinary method of connecting a pair of wheels, or a wheel and a rack, and the only method which insures the exact maintenance of a given numerical velocity-ratio, is by means of a series of alternate ridges and hollows parallel or nearly parallel, to the successive lines of contact of the ideal smooth wheels, whose velocity-ratio would be the same with that of the toothed wheels. The ridges are called *teeth;* the hollows, *spaces.* The teeth of the driver push those of the follower before them, and in so doing sliding takes place between them in a direction across their lines of contact.

The *pitch-surfaces* of a pair of toothed wheels are the ideal smooth surfaces, which would have the same comparative motion by rolling contact which the actual wheels have by the sliding contact of their teeth. The *pitch-circles* of a pair of circular toothed wheels are sections of their pitch-surfaces, made for *spur-wheels* (that is, for wheels whose axes are parallel) by a plane at right angles to the axes, and for bevel wheels by a sphere described about the common apex. For a pair of skew-bevel wheels the pitch-circles are a pair of contiguous rectangular sections of the pitch-surfaces. The *pitch-point* is the point of contact of the pitch-circle.

The pitch-surface of a wheel lies intermediate between the points of the teeth and the bottoms of the hollows between them. That part of the acting surface of a tooth which projects beyond the pitch-surface is called the *face;* that part which lies within the pitch-surface, the *flank.*

Teeth, when not otherwise specified, are understood to be made in one piece with the wheel; the material being generally cast-iron, brass, or bronze. Separate teeth, fixed into mortises in the rim of the wheel, are called *cogs.* A *pinion* is a small toothed wheel; a *trundle* is a pinion with cylindrical *staves* for teeth.

The radius of the pitch-circle of a wheel is called the *geometrical radius;* a circle touching the ends of the teeth is called the *addendum circle,* and its radius the *real radius;* the difference between these radii, being the projection of the teeth beyond the pitch-surface, is called the *addendum.*

The distance, measured along the pitch-circle, from the face of one tooth to the face of the next, is called the *pitch.* The pitch and the number of teeth in wheels are regulated by the following principles:—

I. In wheels which rotate continuously for one revolution or more, it is obviously necessary *that the pitch should be an aliquot part of the circumference.*

In wheels which reciprocate without performing a complete revolution this condition is not necessary. Such wheels are called *sectors.*

II. In order that a pair of wheels, or a wheel and a rack, may work correctly together, it is in all cases essential *that the pitch should be the same in each.*

III. Hence, in any pair of circular wheels which work together, the numbers of teeth in a complete circumference are directly as the radii, and inversely as the angular-velocities.

IV. Hence also in any pair of circular wheels which rotate continuously for one revolution or more, the ratio of the numbers of teeth and its reciprocal, the angular-velocity-ratio, must be expressible in whole numbers.

From this principle arise problems of a kind which will be referred to in treating of *Trains of Mechanism.*

V. Let n, N be the respective numbers of teeth in a pair of wheels, N being the greater. Let t, T be a pair of teeth in the smaller and larger wheel respectively, which at a particular instant work together. It is required to find, first, how many pairs of teeth must pass the line of contact of the pitch-surfaces before t and T work together again (let this number be called a); and, secondly, with how many different teeth of the larger wheel the tooth t will work at different times (let this number be called b); thirdly, with how many different teeth of the smaller wheel the tooth T will work at different times (let this be called c).

CASE 1. If n is a divisor of N,

$$a = \mathrm{N}; \; b = \frac{\mathrm{N}}{n}; \; c = 1. \quad . \quad . \quad . \quad (29.)$$

CASE 2. If the greatest common divisor of N and n be d, a number less than n, so that $n = md$; $\mathrm{N} = \mathrm{M}d$; then

$$a = m\mathrm{N} = \mathrm{M}n = \mathrm{M}md; \; b = \mathrm{M}; \; c = m. \quad . \quad (30.)$$

CASE 3. If N and n be prime to each other,

$$a = \mathrm{N}n; \; b = \mathrm{N}; \; c = n. \quad . \quad . \quad . \quad (31.)$$

It is considered desirable by millwrights, with a view to the preservation of the uniformity of shape of the teeth of a pair of wheels, that each given tooth in one wheel should work with as many different teeth in the other wheel as possible. They therefore study that the numbers of teeth in each pair of wheels which work together shall either be prime to each other, or shall have their greatest common divisor as small as is consistent with a velocity-ratio suited for the purposes of the machine.

61. *Sliding Contact—Forms of the Teeth of Spur-wheels and Racks.*—A line of connection of two pieces in sliding contact is a line perpendicular to their surfaces at a point where they touch. Bearing this in mind, the principle of the comparative motion of a pair of teeth belonging to a pair of spur-wheels, or to a spur-wheel and a rack, is found by applying the principles stated generally in §§ 52 and 53 to the case of parallel axes for a pair of spur-wheels, and to the case of an axis perpendicular to the direction of shifting for a wheel and a rack.

In fig. 17, let C_1, C_2 be the centres of a pair of spur-wheels; $B_1IB'_1$, $B_2IB'_2$, portions of their pitch-circles, touching at I, the pitch-point. Let the wheel 1 be the driver, and the wheel 2 the follower.

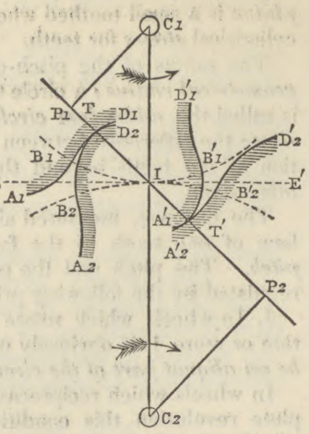


Fig 17.

Let $D_1TB_1A_1$, $D_2TB_2A_2$ be the positions, at a given instant, of the acting surfaces of a pair of teeth in the driver and follower respectively, touching each other at T; the line of connection of those teeth is P_1P_2, perpendicular to their surfaces at T. Let C_1P_1, C_2P_2, be perpendiculars let fall from the centres of the wheels on the line of contact. Then, by sect. 52, the angular-velocity-ratio is

$$\frac{\alpha_2}{\alpha_1} = \frac{\overline{C_1P_1}}{\overline{C_2P_2}} \quad . \quad . \quad . \quad . \quad (32.)$$

The following principles regulate the forms of the teeth and their relative motions:—

I. The angular-velocity-ratio due to the sliding contact of the teeth will be the same with that due to the rolling contact of the pitch-circles, if the line of connection of the teeth cuts the line of centres at the pitch-point.

For, let P_1P_2 cut the line of centres at I; then, by similar triangles,

$$\alpha_1 : \alpha_2 : : \overline{C_2P_2} : \overline{C_1P_1} : : \overline{IC_2} : : \overline{IC_1} ; \quad . \quad (33.)$$

which is also the angular-velocity-ratio due to the rolling contact of the circles $B_1IB'_1$, $B_2IB'_2$.

This principle determines the *forms* of all teeth of spur-wheels. It also determines the forms of the teeth of straight racks, if one of the centres be removed, and a straight line EIE', parallel to the direction of motion of the rack, and perpendicular to C_1IC_2, be substituted for a pitch-circle.

II. The component of the velocity of the point of contact of the teeth T along the line of connection is,

$$\alpha_1 \cdot \overline{C_1P_1} = \alpha_2 \cdot \overline{C_2P_2}. \quad . \quad . \quad . \quad (34.)$$

III. The relative velocity perpendicular to P_1P_2 of the teeth at their point of contact,—that is, their *velocity of sliding* on each other,—is found by supposing one of the wheels, such as 1, to be fixed; the line of centres C_1C_2 to rotate backwards round C_1 with the angular velocity α_1, and the wheel 2 to rotate round C_2 as before, with the angular velocity α_2 relatively to the line of centres C_1C_2, so as to have the same motion as if its pitch-circle *rolled* on the pitch-circle of the first wheel. Thus the *relative* motion of the wheels is unchanged; but 1 is considered as fixed, and 2 has the *total motion* given by the principles of sects. 42 and 43; that is, a rotation about the instantaneous axis I, with the angular velocity $\alpha_1 + \alpha_2$. Hence the *velocity of sliding* is that due to this rotation about I, with the radius IT; that is to say, its value is

$$(\alpha_1 + \alpha_2) \cdot \overline{IT} ; \quad . \quad . \quad . \quad . \quad (35.)$$

so that it is greater the further the point of contact is from the line of centres; and at the instant when that point passes the line of centres, and coincides with the *pitch-point*, the velocity of sliding is null, and the action of the teeth is, for the instant, that of rolling contact.

IV. The *path of contact* is the line traversing the various positions of the point T. If the line of connection preserves always the same position, the path of contact coincides with it, and is straight; in other cases the path of contact is curved.

It is divided by the pitch-point I into two parts: the *arc or line of approach* described by T in approaching the line of centres, and the *arc* or *line of recess* described by T after having passed the line of centres.

During the *approach*, the *flank* D_1B_1 of the driving tooth drives the *face* D_2B_2 of the following tooth, and the teeth are sliding *towards* each other. During the *recess* (in which the position of the teeth is exemplified in the figure by curves marked with accented letters), the *face* $B'_1A'_1$ of the driving tooth drives the *flank* $B'_2A'_2$ of the following tooth, and the teeth are sliding *from* each other.

The path of contact is bounded where the approach commences by the addendum-circle of the follower, and where the recess terminates by the addendum-circle of the driver. The length of the path of contact should be such that there shall always be at least one pair of teeth in contact; and it is better still to make it so long that there shall always be at least two pairs of teeth in contact.

V. The *obliquity* of the action of the teeth is the angle $EIT = IC_1P_1 = IC_2P_2$.

In practice it is found desirable that the mean value of the obliquity of action during the contact of teeth should not exceed 15°, nor the maximum value 30°.

It is unnecessary to give separate figures and demonstrations for inside gearing. The only modification required in the formulæ is, that in equation 3 the *difference* of the angular velocities should be substituted for their sum.

62. *Involute Teeth.*—The simplest form of tooth which fulfils the conditions of sect. 61 is obtained in the following manner (see fig. 18). Let C_1, C_2 be the centres of two wheels, $B_1IB'_1$, $B_2IB'_2$ their pitch-circles, I the pitch-point; let the obliquity of action of the teeth be constant, so that the same straight line P_1IP_2 shall represent at once the constant line of connection of teeth and the path of contact. Draw C_1P_1, C_2P_2 perpendicular to P_1IP_2, and with those lines as radii describe about the centres of the wheels the circles D'_1, $D_2D'_2$, called *base-circles*. It is evident that the radii of the base-circles bear to each other the same proportions as the radii of the pitch-circles; and also that

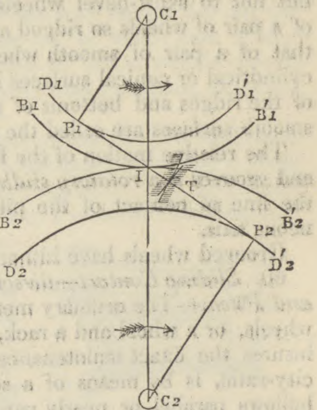


Fig. 18.

$$\left.\begin{array}{l} \overline{C_1P_1} = \overline{IC_1} \cdot \cos \cdot \text{obliquity} \\ \overline{C_2P_2} = \overline{IC_2} \cdot \cos \cdot \text{obliquity} \end{array}\right\} \quad . \quad . \quad . \quad (36.)$$

(The obliquity which is found to answer best in practice is about 14½°; its cosine is about $\frac{31}{32}$, and its sine about $\frac{1}{4}$. These values, though not absolutely exact, are near enough to the truth for practical purposes.)

Suppose the base-circles to be a pair of circular pulleys connected by means of a cord whose course from pulley to pulley is P_1IP_2. As the line of connection of those pulleys is the same with that of the proposed teeth, they will rotate with the required velocity-ratio. Now, suppose a tracing point T to be fixed to the cord, so as to be carried along the path of contact P_1IP_2, that point will trace, on a plane rotating along with the wheel 1, part of the involute of the base-circle $D_1D'_1$; and on a plane rotating along with the wheel 2, part of the involute of the base-circle $D_2D'_2$; and the two curves so traced will always touch each other in the required point of contact T, and will therefore fulfil the condition required by principle I. of sect. 61.

Consequently, one of the forms suitable for the teeth of wheels is the involute of a circle; and the obliquity of the action of such teeth is the angle whose cosine is the ratio of the radius of their base-circle to that of the pitch-circle of the wheel.

All involute teeth of the same pitch work smoothly together.

To find the length of the path of contact on either side of the pitch-point I, it is to be observed that the distance between the fronts of two successive teeth, as measured along P_1IP_2, is less than the pitch in the ratio of cos · obliquity : 1; and, consequently, that if distances equal to the pitch be marked off either way from I towards P_1 and P_2 respectively, as the extremities of the path of contact; and if, according to principle IV. of sect. 61, the addendum-circles be described through the points so found, there will always be at least two pairs of teeth in action at once. In practice it is usual to make the path of contact somewhat longer, viz., about $2\frac{4}{10}$th times the pitch; and with this length of path, and the obliquity already mentioned of $14\frac{1}{2}°$, the addendum is about $\frac{3}{10}$ths of the pitch.

The teeth of a *rack*, to work correctly with wheels having involute teeth, should have plane surfaces perpendicular to the line of connection, and consequently making, with the direction of motion of the rack, angles equal to the complement of the obliquity of action.

63. *Teeth for a given Path of Contact—Mr Sang's method.*—In the preceding section the form of the teeth is found by assuming a figure for the path of contact, viz., the straight line. Any other convenient figure may be assumed for the path of contact, and the corresponding forms of the teeth found, by determining what curves a point T, moving along the assumed path of contact, will trace on two discs rotating round the centres of the wheels with angular velocities bearing that relation to the component velocity of T along TI, which is given by principle II. of sect. 61, and by equation 34. This method of finding the forms of the teeth of wheels forms the subject of an elaborate and most interesting treatise by Mr Edward Sang.

All wheels having teeth of the same pitch, traced from the same path of contact, work correctly together, and are said to belong to the *same set*.

64. *Teeth traced by Rolling Curves.*—If any curve R be rolled on the inside of the pitch-circle BB of a wheel, it appears, from sect. 42, that the instantaneous axis of the rolling curve at any instant will be at the point I, where it touches the pitch-circle for the moment, and that consequently the line AT, traced by a tracing-point T, fixed to the rolling curve upon the plane of the wheel, will be everywhere perpendicular to the straight line TI; so that the traced curve AT will be suitable for the flank of a tooth, in which T is the point of contact corresponding to the position I of the pitch-point. If the same rolling curve R, with the same tracing-point T, be rolled on the *outside* of any other pitch-circle, it will have the *face* of a tooth suitable to work with the *flank* AT.

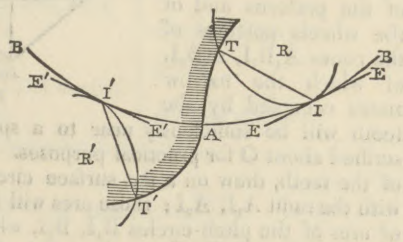


Fig. 19.

In like manner, if either the same or any other rolling curve R′ be rolled the opposite way, on the *outside* of the pitch-circle BB, so that the tracing point T′ shall start from A, it will trace the *face* AT′ of a tooth suitable to work with a *flank* traced by rolling the same curve R′ with the same tracing-point T′ *inside* any other pitch-circle.

The figure of the *path of contact* is that traced on a fixed plane by the tracing point, when the rolling curve is rotated in such a manner as always to touch a fixed straight line EIE (or E′I′E′, as the case may be) at a fixed point I (or I′).

If the same rolling curve and tracing point be used to trace both the faces and the flanks of the teeth of a number of wheels of different sizes but of the same pitch, all those wheels will work correctly together, and will form a *set*. The teeth of a *rack*, of the same set, are traced by rolling the rolling curve on both sides of a straight line.

The teeth of wheels of any figure, as well as of circular wheels, may be traced by rolling curves on their pitch-surfaces; and all teeth of the same pitch, traced by the same rolling curve with the same tracing-point, will work together correctly if their pitch-surfaces are in rolling contact.

65. *Epicycloidal Teeth.*—The most convenient rolling curve is the circle. The path of contact which it traces is identical with itself; and the flanks of the teeth are internal and their faces external epicycloids for wheels, and both flanks and faces are cycloids for a rack.

For a pitch-circle of twice the radius of the rolling or *describing* circle (as it is called), the internal epicycloid is a straight line, being, in fact, a diameter of the pitch-circle, so that the flanks of the teeth for such a pitch-circle are planes radiating from the axis. For a smaller pitch-circle the flanks would be convex and *incurved* or *under-cut*, which would be inconvenient; therefore the smallest wheel of a set should have its pitch-circle of twice the radius of the describing circle, so that the flanks may be either straight or concave.

In fig. 20, let BB′ be part of the pitch-circle of a wheel with epicycloidal teeth; CIC the line of centres; I the pitch-point; EIE′ a straight tangent to the pitch-circle at that point; R the internal, and R′ the equal external describing circles, so placed as to touch the pitch-circle and each other at I. Let DID′ be the path of contact, consisting of the arc of approach DI, and the arc of recess ID′. In order that there may always be at least two pairs of teeth in action, each of those arcs should be equal to the pitch.

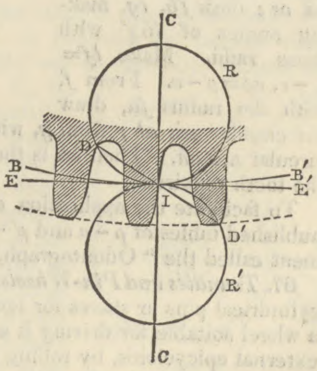


Fig. 20.

The obliquity of the action in passing the line of centres is nothing; the maximum obliquity is the angle EID = E′ID; and the mean obliquity is one-half of that angle.

It appears from experience that the mean obliquity should not exceed 15°; therefore the maximum obliquity should be about 30°; therefore the arcs DI = ID′ should each be one-sixth of a circumference; therefore the circumference of the describing circle should be *six times the pitch*.

It follows, that the smallest pinion of a set, in which pinion the flanks are straight, should have twelve teeth.

66. *Nearly Epicycloidal Teeth—Mr Willis's method.*—To facilitate the drawing of epicycloidal teeth in practice, Mr Willis has shown how to approximate to their figure by means of two circular arcs,—one concave, for the flank, the other convex, for the face; and each having for its radius the *mean* radius of curvature of the epicycloidal arc. Mr Willis's formulæ are founded on the following properties of epicycloids:—

Let R be the radius of the pitch-circle; r that of the describing circle; θ the angle made by the normal TI to the epicycloid at a given point T, with a tangent to the circle at I; that is, the obliquity of the action at T.

Then the radius of curvature of the epicycloid at T is,—

$$\left.\begin{aligned}\text{For an internal epicycloid, } \rho &= 4r\cdot\sin\theta\,\frac{R-r}{R-2r}\\ \text{For an external epicycloid, } \rho' &= 4r\cdot\sin\theta\,\frac{R+r}{R+2r}\end{aligned}\right\}\quad(37.)$$

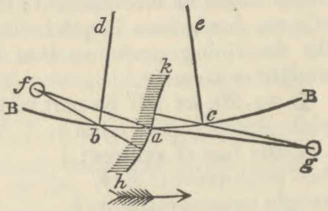
Also, to find the position of the centres of curvature relatively to the pitch-circle, we have (denoting the chord of the describing circle $\overline{TI}$ by c)—$\overline{TI}=c=2r\cdot\sin\theta$; and therefore

$$\left.\begin{aligned}\text{For the flank, } \rho-c &= 2r\cdot\sin\theta\,\frac{R}{R-2r}\\ \text{For the face, } \rho'-c &= 2r\cdot\sin\theta\,\frac{R}{R+2r}\end{aligned}\right\}\quad.\quad(38.)$$

For the proportions approved of by Mr Willis, $\sin\theta=\frac{1}{4}$ nearly; $r=p$ (the pitch) nearly; $c=\frac{p}{2}$ nearly; and if N be the number of teeth in the wheel, $\frac{r}{R}=\frac{6}{N}$ nearly; therefore approximately,

$$\left.\begin{aligned}\rho-c &= \frac{p}{2}\cdot\frac{N}{N-12}\\ \rho'-c &= \frac{p}{2}\cdot\frac{N}{N+12}\end{aligned}\right\}\quad.\quad.\quad.\quad(39.)$$

Hence the following construction (fig. 21):—Let BB be part of the pitch-circle; a the point where a tooth is to cross it. Set off $ab=ac=\frac{p}{2}$. Draw radii bd, ce; draw fb, cg, making angles of $75\frac{1}{2}$° with those radii. Make $bf=\rho-c$, $cg=\rho-c$. From f, with the radius fa, draw the circular arc ah; from g, with the radius ga, draw the circular arc ak. Then ah is the face, and ak the flank of the tooth required.



Fig, 21.

To facilitate the application of this rule, Mr Willis has published tables of $\rho-c$ and $\rho'-c$, and invented an instrument called the "Odontograph."

67. *Trundles and Pin-Wheels.*—If a wheel or trundle have cylindrical pins or staves for teeth, the faces of the teeth of a wheel suitable for driving it are described by first tracing external epicycloids, by rolling the pitch-circle of the pin-wheel or trundle on the pitch-circle of the driving-wheel, with the centre of a stave for a tracing-point, and then drawing curves parallel to, and within the epicycloids, at a distance from them equal to the radius of a stave. Trundles having only six staves will work with large wheels.

68. *Backs of Teeth and Spaces.*—Toothed wheels being in general intended to rotate either way, the *backs* of the teeth are made similar to the fronts. The *space* between two teeth, measured on the pitch-circle, is made about $\frac{1}{5}$th part wider than the thickness of the tooth on the pitch-circle; that is to say,

$$\text{Thickness of tooth} = \frac{5}{11}\text{ pitch.}$$

$$\text{Width of space} \quad = \frac{6}{11}\text{ pitch.}$$

The difference of $\frac{1}{11}$ of the pitch is called the *back-lash.* The clearance allowed between the points of teeth and the bottoms of the spaces between the teeth of the other wheel is about $\frac{1}{10}$th of the pitch.

69. *Stepped and Helical Teeth.*—Dr Hooke invented the making of the fronts of teeth in a series of steps with a view to increase the smoothness of action. A wheel thus formed resembles in shape a series of equal and similar toothed discs placed side by side, with the teeth of each a little behind those of the preceding disc. He also invented, with the same object, teeth whose fronts, instead of being parallel to the line of contact of the pitch-circles, cross it obliquely, so as to be of a screw-like or helical form. In wheel-work of this kind the contact of each pair of teeth commences at the foremost end of the helical front, and terminates at the aftermost end; and the helix is of such a pitch that the contact of one pair of teeth shall not terminate until that of the next pair has commenced.

Stepped and helical teeth have the desired effect of increasing the smoothness of motion, but they require more difficult and expensive workmanship than common teeth; and helical teeth are, besides, open to the objection that they exert a laterally oblique pressure, which tends to increase resistance, and unduly strain the machinery.

70. *Teeth of Bevel-Wheels.*—The acting surfaces of the teeth of bevel-wheels are of the conical kind, generated by the motion of a line passing through the common apex of the pitch-cones, while its extremity is carried round the outlines of the cross section of the teeth made by a sphere described about that apex.

The operations of describing the exact figures of the teeth of bevel-wheels, whether by involutes or by rolling curves, are in every respect analogous to those for describing the figures of the teeth of spur-wheels, except that in the case of bevel-wheels all those operations are to be performed on the surface of a sphere described about the apex instead of on a plane, substituting *poles* for *centres*, and *great circles* for *straight lines.*

In consideration of the practical difficulty, especially in the case of large wheels, of obtaining an accurate spherical surface, and of drawing upon it, when obtained, the following *approximate* method, proposed originally by Tredgold, is generally used:—

Let O (fig. 22) be the common apex of a pair of bevel-wheels; OB_1I, OB_2I their pitch-cones; OC_1, OC_2 their axes; OI their line of contact. Perpendicular to OI draw A_1IA_2, cutting the axes in A_1, A_2; make the outer rims of the patterns and of the wheels portions of the cones A_1B_1I, A_2B_2I, of which the narrow zones occupied by the teeth will be sufficiently near to a spherical surface described about O for practical purposes. To find the figures of the teeth, draw on a flat surface circular arcs ID_1, ID_2, with the radii A_1I, A_2I; those arcs will be the *developments* of arcs of the pitch-circles B_1I, B_2I, when the conical surfaces A_1B_1I, A_2B_2I are spread out flat. Describe the figures of teeth for the developed arcs as for a pair of spur-wheels; then wrap the developed arcs on the cones, so as to make them coincide with the pitch-circles, and trace the teeth on the conical surfaces.

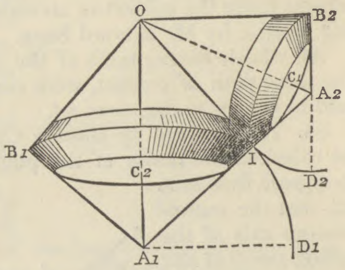


Fig. 22.

71. *Teeth of Skew-Bevel Wheels.*—The crests of the teeth of a skew-bevel wheel are parallel to the generating straight line of the hyperboloidal pitch-surface; and the transverse sections of the teeth at a given pitch-circle are similar to those of the teeth of a bevel-wheel whose pitch-surface is a cone touching the hyperboloidal surface at the given circle.

72. *Cams.*—A *cam* is a single tooth, either rotating continuously or oscillating, and driving a sliding or turning piece either constantly or at intervals. All the principles which have been stated in sect. 61 as being applicable to teeth, are applicable to cams; but in designing cams it is not usual to determine or take into consideration the form of

the ideal pitch-surface, which would give the same comparative motion by rolling contact that the cam gives by sliding contact.

73. *Screws.*—The figure of a screw is that of a convex or concave cylinder, with one or more helical projections, called *threads*, winding round it. Convex and concave screws are distinguished technically by the respective names of *male* and *female;* a short concave screw is called a *nut;* and when a *screw* is spoken of without qualification, a *convex* screw is usually understood.

The relation between the *advance* and the *rotation*, which compose the motion of a screw working in contact with a fixed screw or helical guide, has already been demonstrated in sect. 47; and the same relation exists between the magnitudes of the rotation of a screw about a fixed axis and the advance of a shifting nut in which it rotates. The advance of the nut takes places in the opposite direction to that of the advance of the screw in the case in which the nut is fixed. The *pitch* or *axial pitch* of a screw has the meaning assigned to it in that section, viz., the distance, measured parallel to the axis, between the corresponding points in two successive turns of the *same thread.* If, therefore, the screw has several equidistant threads, the true pitch is equal to the *divided axial pitch*, as measured between two adjacent threads, multiplied by the number of threads.

If a helix be described round the screw, crossing each turn of the thread at right angles, the distance between two corresponding points on two successive turns of the same thread, measured along this *normal helix*, may be called the *normal pitch;* and when the screw has more than one thread, the normal pitch from thread to thread may be called the *normal divided pitch.*

The distance from thread to thread, measured on a circle, described about the axis of the screw, called the pitch-circle, may be called the *circumferential pitch;* for a screw of one thread it is one circumference; for a screw of n threads, $\frac{\text{one circumference}}{n}$.

Let r denote the radius of the pitch circle;
n the number of threads;
θ the obliquity of the threads to the pitch circle, and of the normal helix to the axis.

$$\left.\begin{matrix} \mathrm{P}_a \\ \frac{\mathrm{P}_a}{n} = p_a \end{matrix}\right\} \text{ the axial } \left\{\begin{matrix} \text{pitch,} \\ \text{divided pitch;} \end{matrix}\right.$$

$$\left.\begin{matrix} \mathrm{P}_n \\ \frac{\mathrm{P}_n}{n} = p_n \end{matrix}\right\} \text{ the normal } \left\{\begin{matrix} \text{pitch,} \\ \text{divided pitch;} \end{matrix}\right.$$

P_c the circumferential pitch;

Then—

$$\left.\begin{aligned} p_c &= p_a \cdot \text{cotan}\,\theta = p_n \cdot \text{cosec}\,\theta = \frac{2\pi r}{n}; \\ p_a &= p_n \cdot \quad \sec\theta = p_c \cdot \quad \tan\theta = \frac{2\pi r \cdot \tan\theta}{n}; \\ p_n &= p_c \cdot \quad \sin\theta = p_a \cdot \quad \cos\theta = \frac{2\pi r \cdot \sin\theta}{n}. \end{aligned}\right\} \quad . \quad (40.)$$

If a screw rotates, the number of threads which pass a fixed point in one revolution is the number of threads in the screw.

A pair of convex screws, each rotating about its axis, are used as an elementary combination to transmit motion by the sliding contact of their threads. Such screws are commonly called *endless screws.* At the point of contact of the screws their threads must be parallel; and their line of connection is the common perpendicular to the acting surfaces of the threads at their point of contact. Hence the following principles:—

I. If the screws are both right-handed or both left-handed, the angle between the directions of their axes is the sum of their obliquities; if one is right-handed and the other left-handed, that angle is the difference of their obliquities.

II. The normal pitch for a screw of one thread, and the normal divided pitch for a screw of more than one thread, must be the same in each screw.

III. The angular velocities of the screws are inversely as their numbers of threads.

Dr Hooke's wheels with oblique or helical teeth, are in fact screws of many threads, and of large diameters as compared with their lengths.

The ordinary position of a pair of endless screws is with their axes at right angles to each other. When one is of considerably greater diameter than the other, the larger is commonly called in practice a *wheel*, the name *screw* being applied to the smaller only; but they are nevertheless both screws in fact.

To make the teeth of a pair of endless screws fit correctly and work smoothly, a hardened steel screw is made of the figure of the smaller screw, with its thread or threads notched so as to form a cutting tool; the larger screw, or "wheel," is cast approximately of the required figure; the larger screw and the steel screw are fitted up in their proper relative position, and made to rotate in contact with each other by turning the steel screw, which cuts the threads of the larger screw to their true figure.

74. *Coupling of Parallel Axes—Oldham's Coupling.*—A *coupling* is a mode of connecting a pair of shafts so that they shall rotate in the same direction with the same mean angular velocity. If the axes of the shafts are in the same straight line, the coupling consists in so connecting their contiguous ends that they shall rotate as one piece; but if the axes are not in the same straight line, combinations of mechanism are required. A coupling for parallel shafts which acts by *sliding contact* was invented by Oldham, and is represented in fig. 23. C_1, C_2 are the axes of the two parallel shafts; D_1, D_2 two discs facing each other, fixed on the ends of the two shafts respectively; $\mathrm{E}_1\mathrm{E}_1$, a bar sliding in a diametral groove in the face of D_1; $\mathrm{E}_2\mathrm{E}_2$ a bar sliding in a diametral groove in the face of D_2: those bars are fixed together at A, so as to form a rigid cross. The angular velocities of the two discs and of the cross are all equal at every instant; the middle point of the cross, at A, revolves in the dotted circle described upon the line of centres C_1 C_2 as a diameter, twice for each turn of the discs and cross; the instantaneous axis of rotation of the cross at any instant is at I, the point in the circle $\mathrm{C}_1\mathrm{C}_2$ diametrically opposite to A.

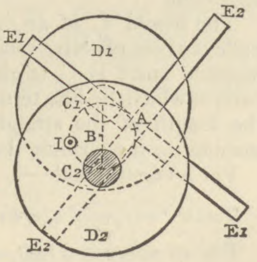


Fig. 23.

Oldham's coupling may be used with advantage where the axes of the shafts are intended to be as nearly in the same straight line as is possible, but where there is some doubt as to the practicability or permanency of their exact continuity.

75. *Wrapping Connectors—Belts, Cords, and Chains.*—Flat belts of leather or of gutta percha, round cords of catgut, hemp, or other material, and metal chains, are used as wrapping connectors to transmit rotatory motion between pairs of pulleys and drums.

Belts (the most frequently used of all wrapping connectors) require nearly cylindrical pulleys. A belt tends to move towards that part of a pulley whose radius is greatest; pulleys for belts, therefore, are slightly swelled in the middle, in order that the belt may remain on the pulley, unless forcibly shifted. A belt when in motion is shifted off a pulley, or from one pulley on to another of equal size alongside of it, by pressing against that part of the belt which is moving *towards* the pulley.

Cords require either cylindrical drums with ledges or grooved pulleys.

Chains require pulleys or drums, grooved, notched, and toothed, so as to fit the links of the chain.

Wrapping connectors for communicating continuous motion are endless.

Wrapping connectors for communicating reciprocating motion have usually their ends made fast to the pulleys or drums which they connect, and which in this case may be sectors.

The line of connection of two pieces connected by a wrapping connector is the centre line of the belt, cord, or chain; and the comparative motions of the pieces are determined by the principles of sect. 52, if both pieces turn; and of sect. 53, if one turns and the other shifts, in which latter case the motion must be reciprocating.

The *pitch-line* of a pulley or drum is a curve to which the line of connection is always a tangent; that is to say, it is a curve parallel to the acting surface of the pulley or drum, and distant from it by half the thickness of the wrapping connector.

Pulleys and drums for communicating a constant velocity-ratio are circular. The *effective radius,* or radius of the pitch-circle of a circular pulley or drum, is equal to the real radius added to half the thickness of the connector. The angular velocities of a pair of connected circular pulleys or drums are inversely as the effective radii.

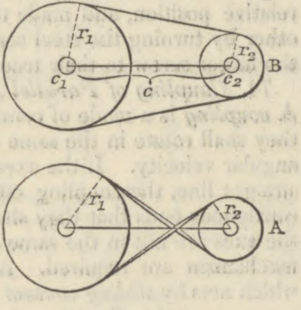


Fig. 24.

A *crossed* belt, as in fig. 24, A, reverses the direction of the rotation communicated; an *uncrossed* belt, as in fig. 24, B, preserves that direction.

The *length* L of an endless belt connecting a pair of pulleys whose effective radii are r_1, r_2, with parallel axes whose distance apart is C, is given by the following formulæ, in each of which the first term, containing the radical, expresses the length of the straight parts of the belt, and the remainder of the formula the length of the curved parts.

For a crossed belt,—

$$\mathrm{L}=2\sqrt{c^2-(r_1+r_2)^2}+(r_1+r_2)\left(\pi-2\,\mathrm{arc}\cdot\sin\frac{r_1+r_2}{c}\right) \quad . \; . \; (41\ \mathrm{A.})$$

For an uncrossed belt,—

$$\mathrm{L}=2\sqrt{\{c^2-(r_1-r_2)^2\}}+\pi(r_1-r_2)+2(r_1-r_2)\,\mathrm{arc}\cdot\sin\frac{r_1-r_2}{c} \quad (41\ \mathrm{B.})$$

in which r_1 is the greater radius, and r_2 the less.

When the axes of a pair of pulleys are not parallel, the pulleys should be so placed that the part of the belt which is *approaching* each pulley shall be in the plane of the pulley.

76. *Speed-Cones*—(See fig. 25.)—A pair of speed-cones is a contrivance for varying and adjusting the velocity-ratio communicated between a pair of parallel shafts by means of a belt. The speed-cones are either continuous cones or conoids, as A, B, whose velocity-ratio can be varied gradually while they are in motion by shifting the belt, or sets of pulleys whose radii vary by steps, as C, D, in which case the velocity-ratio can be changed by shifting the belt from one pair of pulleys to another.

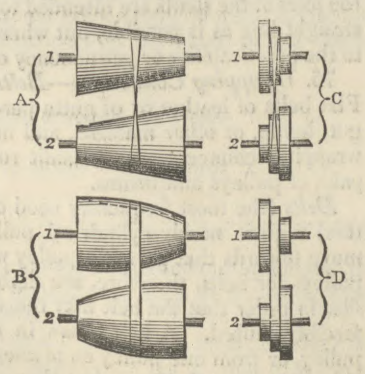


Fig. 25.

In order that the belt may fit accurately in every possible position on a pair of speed-cones, the quantity L must be constant, in equations 41 A or 41 B, according as the belt is crossed or uncrossed.

For a *crossed* belt, as in A and C, fig. 25, L depends solely on c and on r_1+r_2. Now c is constant because the axes are parallel; therefore the *sum of the radii* of the pitch-circles connected in every position of the belt is to be constant. That condition is fulfilled by a pair of continuous cones generated by the revolution of two straight lines inclined opposite ways to their respective axes at equal angles.

For an uncrossed belt, the quantity L in equation 41 B is to be made constant. The exact fulfilment of this condition requires the solution of a transcendental equation; but it may be fulfilled with accuracy sufficient for practical purposes by using, instead of 41 B, the following *approximate* equation:—

$$\mathrm{L\ nearly}=2c+\pi(r_1+r_2)+\frac{(r_1-r_2)^2}{c}. \quad \cdot \quad (42.)$$

The following is the most convenient practical rule for the application of this equation:—

Let the speed-cones be equal and similar conoids, as in B, fig. 25, but with their large and small ends turned opposite ways. Let r_1 be the radius of the large end of each, r_2 that of the small end, r_0 that of the middle; and let v be the *sagitta,* measured perpendicular to the axes, of the arc by whose revolution each of the conoids is generated, or, in other words, the *bulging* of the conoids in the middle of their length. Then

$$v=r_0-\frac{r_1+r_2}{2}=\frac{(r_1-r_2)^2}{2\pi c} \quad . \; . \; . \quad (43.)$$

$2\pi=6{\cdot}2832$; but 6 may be used in most practical cases without sensible error.

The radii at the middle and end being thus determined, make the generating curve an arc either of a circle or of a parabola.

77. *Linkwork in General.*—The pieces which are connected by linkwork, if they rotate or oscillate, are usually called *cranks, beams,* and *levers.* The *link* by which they are connected is a rigid rod or bar, which may be straight, or of any other figure; the straight figure, being the most favourable to strength, is always used when there is no special reason to the contrary. The link is known by various names under various circumstances, such as *coupling-rod, connecting-rod, crank-rod, eccentric-rod,* &c. It is attached to the pieces which it connects by two pins, about which it is free to turn. The effect of the link is to maintain the distance between the axes of those pins invariable; hence the common perpendicular of the axes of the pins is *the line of connection,* and its extremities may be called the *connected points.* In a turning piece, the perpendicular let fall from its connected point upon its axis of rotation is the *arm* or *crank-arm.*

The axes of rotation of a pair of turning pieces connected by a link are almost always parallel, and perpendicular to the line of connection; in which case the angular velocity-ratio at any instant is the reciprocal of the ratio of the common perpendiculars let fall from the line of connection upon the respective axes of rotation.

If at any instant the direction of one of the crank-arms coincides with the line of connection, the common perpendicular of the line of connection and the axis of that crank-arm vanishes, and the directional relation of the motions becomes indeterminate. The position of the connected point of the crank-arm in question at such an instant is called a *dead-point.* The velocity of the other connected point at such an instant is null, unless it also reaches a dead-point at the same instant, so that the line of connection is in the plane of the two axes of rotation, in which case the velocity-ratio is indeterminate. Examples of dead points, and of the means of preventing the inconvenience which they tend to occasion, will appear in the sequel.

78. *Coupling of Parallel Axes.*—Two or more parallel shafts (such as those of a locomotive engine, with two or more pairs of driving wheels) are made to rotate with constantly equal angular velocities by having equal cranks, which are maintained parallel by a coupling-rod of such a length that the line of connection is equal to the distance between the axes. The cranks pass their dead points simultaneously. To obviate the unsteadiness of motion which this tends to cause, the shafts are provided with a second set of cranks at right angles to the first, connected by means of a similar coupling-rod, so that one set of cranks pass their dead points at the instant when the other set are furthest from theirs.

79. *Comparative Motion of Connected Points.*—As the link is a rigid body, it is obvious that its action in communicating motion may be determined by finding the comparative motion of the connected points, according to the principles laid down in sect. 48; and this is often the most convenient method of proceeding.

If a connected point belongs to a turning piece, the direction of its motion at a given instant is perpendicular to the plane containing the axis and crank-arm of the piece. If a connected point belongs to a shifting piece, the direction of its motion at any instant is given, and a plane can be drawn perpendicular to that direction.

The line of intersection of the planes perpendicular to the paths of the two connected points at a given instant, is the *instantaneous axis of the link* at that instant; and the *velocities of the connected points are directly as their distances from that axis.*

In drawing on a plane surface, the two planes perpendicular to the paths of the connected points are represented by two lines (being their sections by a plane normal to them), and the instantaneous axis by a point (fig. 26); and should the length of the two lines render it impracticable to produce them until they actually intersect, the velocity-ratio of the connected points may be found by the principle, that it is equal to the ratio of the segments which a line parallel to the line of connection cuts off from any two lines drawn from a given point, perpendicular respectively to the paths of the connected points.

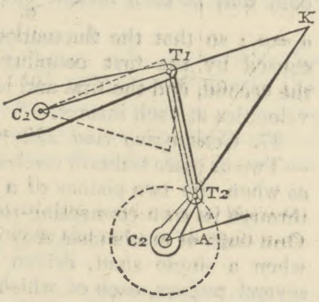


Fig. 26.

To illustrate this by one example: Let C_1 be the axis, and T_1 the connected point of the beam of a steam-engine; T_1T_2 the connecting or crank-rod; T_2 the other connected point, and the centre of the crank-pin; C_2 the axis of the crank and its shaft. Let v_1 denote the velocity of T_1 at any given instant; v_2 that of T_2. To find the ratio of these velocities, produce C_1T_1, C_2T_2, till they intersect in K; K is the instantaneous axis of the connecting rod, and the velocity-ratio is

$$v_1 : v_2 :: \overline{KT_1} : \overline{KT_2} \quad . \quad . \quad . \quad . \quad (44.)$$

Should K be inconveniently far off, draw any triangle with its sides respectively parallel to C_1T_1, C_2T_2, and T_1T_2; the ratio of the two sides first mentioned will be the velocity-ratio required. For example, draw C_2A parallel to C_1T_1, cutting T_1T_2 in A; then

$$v_1 : v_2 :: \overline{C_2A} : \overline{C_2T_2} \quad . \quad . \quad . \quad . \quad (45.)$$

80. *Eccentric.*—An eccentric circular disc fixed on a shaft, and used to give a reciprocating motion to a rod, is in effect a crank-pin of sufficiently large diameter to surround the shaft, and so to avoid the weakening of the shaft which would arise from bending it so as to form an ordinary crank. The centre of the eccentric is its connected point; and its eccentricity, or the distance from that centre to the axis of the shaft, is its crank-arm.

An eccentric may be made capable of having its eccentricity altered by means of an adjusting screw, so as to vary the extent of the reciprocating motion which it communicates.

81. *Reciprocating Pieces—Stroke—Dead Points.*—The distance between the extremities of the path of the connected point in a reciprocating piece (such as the piston of a steam-engine) is called the *stroke* or *length of stroke* of that piece. When it is connected with a continuously turning-piece (such as the crank of a steam-engine) the ends of the stroke of the reciprocating piece correspond to the *dead points* of the path of the connected point of the turning piece, where the line of connection is continuous with, or coincides with the crank-arm.

Let S be the length of stroke of the reciprocating piece, L the length of the line of connection, and R the crank-arm of the continuously turning piece. Then, if the two ends of the stroke be in one straight line with the axis of the crank,

$$S = 2R \; ; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46.)$$

and if these ends be not in one straight line with that axis, then S, L − R, and L + R, are the three sides of a triangle, having the angle opposite S at that axis; so that if θ be the supplement of the arc between the dead points,

$$\left.\begin{aligned} S^2 &= 2(L^2+R^2) - 2(L^2-R^2)\cos\theta \\ \cos\theta &= \frac{2L^2+2R^2-S^2}{2(L^2-R^2)} \end{aligned}\right\} \quad . \quad . \quad (47.)$$

82. *Coupling of Intersecting Axes: Hooke's Universal Joint.*—Intersecting axes are coupled by a contrivance of Hooke's, known as the "universal joint," which belongs to the class of linkwork (see fig. 27). Let O be the point of intersection of the axes OC_1, OC_2, and θ their angle of inclination to each other. The pair of shafts C_1, C , terminate in a pair of forks F_1, F_2, in bearings at the extremities of which turn the gudgeons at the ends of the arms of a rectangular cross, having its centre at O. This cross is the link; the connected points are the centres of the bearings F , F_2. At each instant, each of those points moves at right angles to the central plane of its shaft and fork; therefore the line of intersection of the central planes of the two forks at any instant is the instantaneous axis of the cross, and the *velocity-ratio* of the points F_1, F_2 (which, as the forks are equal, is also the *angular velocity-ratio* of the shafts), is equal to the ratio of the distances of those points from that instantaneous axis. The *mean* value of that velocity-ratio is that of equality; for each successive *quarter-turn* is made by both shafts in the same time, but its actual value fluctuates between the limits—

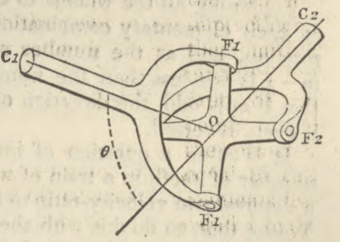


Fig. 27.

$$\left.\begin{aligned} &\frac{a_2}{a_1} = \frac{1}{\cos\theta} \text{ when } F_1 \text{ is in the plane } OC_1C_2 \\ &\text{and } \frac{a_2}{a_1} = \cos\theta \text{ when } F_2 \text{ is in that plane.} \end{aligned}\right\} \quad (48.)$$

Its value at intermediate instants is given by the following equations:—Let φ_1, φ_2 be the angles respectively made by the central planes of the forks and shafts with the plane OC_1C_2 at a given instant; then

$$\left.\begin{aligned}\cos\theta &= \tan\phi_1 \cdot \tan\phi_2 \\ \frac{\alpha_2}{\alpha_1} = -\frac{d\phi_2}{d\phi_1} &= \frac{\tan\phi_1 + \text{cotan}\,\phi_1}{\tan\phi_2 + \text{cotan}\,\phi_2}\end{aligned}\right\} \quad . \quad . \quad (49.)$$

83. *Intermittent Linkwork—Click and Ratchet.*—A *click* acting upon a ratchet-wheel or rack, which it pushes or pulls through a certain arc at each forward stroke, and leaves at rest at each backward stroke, is an example of intermittent linkwork. During the forward stroke, the action of the click is governed by the principles of linkwork; during the backward stroke that action ceases. A *catch* or *pall*, turning on a fixed axis, prevents the ratchet-wheel or rack from reversing its motion.

DIVISION V.—TRAINS OF MECHANISM.

84. *General Principles.*—*A train of mechanism* consists of a series of pieces, each of which is follower to that which drives it, and driver to that which follows it.

The comparative motion of the first driver and last follower is obtained by combining the proportions expressing by their terms the velocity-ratios, and by their signs the directional relations of the several elementary combinations of which the train consists.

85. *Trains of Wheelwork.*—Let A_1, A_2, A_3, &c., A_{m-1}, A_m, denote a series of axes; and α_1, α_2, α_3, &c., α_{m-1}, α_m, their angular velocities. Let the axis A_1 carry a wheel of N_1 teeth, driving a wheel of n_2 teeth on the axis A_2, which carries also a wheel of N_2 teeth, driving a wheel of n_3 teeth on the axis A_3, and so on; the numbers of teeth in drivers being denoted by N's, and in followers by *n*'s, and the axes to which the wheels are fixed being denoted by numbers. Then the resulting velocity-ratio is denoted by

$$\frac{\alpha_m}{\alpha_1} = \frac{\alpha_2}{\alpha_1} \cdot \frac{\alpha_3}{\alpha_2} \cdot \&\text{c.} \;.\;.\; \frac{\alpha_m}{\alpha_{m-1}} = \frac{N_1 \cdot N_2 \,..\, \&\text{c.} \,....\, N_{m-1}}{n_2 \cdot n_3 \,..\, \&\text{c.} \,....\, n_m}; \quad (50.)$$

that is to say, the velocity-ratio of the last and first axes is the ratio of the product of the numbers of teeth in the drivers to the product of the numbers of teeth in the followers.

Supposing all the wheels to be in outside gearing, then, as each elementary combination reverses the direction of rotation, and as the number of elementary combinations $m-1$ is one less than the number of axes m, it is evident that if m is odd, the direction of rotation is preserved, and, if even, reversed.

It is often a question of importance to determine the number of teeth in a train of wheels best suited for giving a determinate velocity-ratio to two axes. It was shown by Young that, to do this with the *least total number of teeth*, the velocity-ratio of each elementary combination should approximate as nearly as possible to 3·59. This would in many cases give too many axes; and, as a useful practical rule, it may be laid down that from 3 to 6 ought to be the limit of the velocity-ratio of an elementary combination in wheelwork. The smallest number of teeth in a pinion ought to be,—for epicycloidal teeth (see sect. 65), *twelve;* but it is still better, for smoothness of motion, not to go below *fifteen*, and for involute teeth the smallest number is about *twenty-four*.

Let $\frac{B}{C}$ be the velocity-ratio required, reduced to its least terms, and let B be greater than C. If $\frac{B}{C}$ is not greater than 6, and C lies between the prescribed minimum number of teeth (which may be called t), and its double $2t$, then one pair of wheels will answer the purpose, and B and C will themselves be the numbers required. Should B and C be inconveniently large, they are, if possible, to be resolved into factors, and those factors (or if they are too small, multiples of them) used for the number of teeth. Should B or C, or both, be at once inconveniently large and prime, then, instead of the exact ratio $\frac{B}{C}$, some ratio approximating to that ratio, and capable of resolution into convenient factors, is to be found by the method of continued fractions.

Should $\frac{B}{C}$ be greater than 6, the best number of elementary combinations $m-1$ will lie between

$$\frac{\log B - \log C}{\log 6} \text{ and } \frac{\log B - \log C}{\log 3}$$

Then, if possible, B and C themselves are to be resolved each into $m-1$ factors (counting 1 as a factor), which factors, or multiples of them, shall be not less than t, nor greater than $6t$; or if B and C contain inconveniently large prime factors, an approximate velocity-ratio, found by the method of continued fractions, is to be substituted for $\frac{B}{C}$ as before.

So far as the result and velocity-ratio is concerned, the *order* of the drivers N and of the followers n is immaterial; but to secure equable wear of the teeth, as explained in sect. 60, the wheels ought to be so arranged that, for each elementary combination, the greatest common divisor of N and n shall be either 1, or as small as possible.

86. *Double Hooke's Coupling.*—It has been shown in section 82 that the velocity-ratio of a pair of shafts, coupled by an universal joint, fluctuates between the limits $\cos\theta$ and $\frac{1}{\cos\theta}$. Hence one or both of the shafts must have a vibratory and unsteady motion, injurious to the mechanism and framework. To obviate this evil a short intermediate shaft is introduced, making equal angles with the first and last shaft, coupled with each of them by a Hooke's joint, and having its own two forks in the same plane. Let α_1, α_2, α_3, be the angular velocities of the first, intermediate, and last shaft in this *train of two Hooke's couplings*. Then, from the principles of sect. 82, it is evident that at each instant $\frac{\alpha_2}{\alpha_1} = \frac{\alpha_2}{\alpha_3}$, and consequently that $\alpha_3 = \alpha_1$; so that the fluctuations of angular velocity-ratio caused by the first coupling are exactly neutralized by the second, and the first and last shafts have equal angular velocities at each instant.

87. *Converging and Diverging Trains of Mechanism.*—Two or more trains of mechanism may *converge* into one; as when the two pistons of a pair of steam-engines, each through its own connecting-rod, act upon one crank-shaft. One train of mechanism may *diverge* into two or more; as when a single shaft, driven by a prime mover, carries several pulleys, each of which drives a different machine. The principles of comparative motion in such converging and diverging trains are the same as in simple trains.

DIVISION VI.—AGGREGATE COMBINATIONS.

88. *General Principles.*—Mr Willis has designated as "Aggregate Combinations" those assemblages of pieces of mechanism in which the motion of one follower is the *resultant* of component motions impressed on it by more than one driver. Two classes of aggregate combinations may be distinguished, which, though not different in their actual nature, differ in the *data* which they present to the designer, and in the method of solution to be followed in questions respecting them.

Class I. comprises those cases in which a piece A is not carried directly by the frame C, but by another piece B, *relatively* to which the motion of A is given,—the motion of the piece B relatively to the frame C being also given. Then the motion of A relatively to the frame C is the *resultant* of the motion of A relatively to B, and of B relatively to C; and that resultant is to be found by the principles already explained in Division III. of this chapter, sects. 36 to 47.

Class II. comprises those cases in which the motions of three points in one follower are determined by their connections with two or with three different drivers, so that the motion of the follower, as a whole, is to be determined by the principles of sect. 48.

This classification is founded on the kinds of problems arising from the combinations. Mr Willis adopts another classification, founded on the *objects* of the combinations, which objects he divides into two classes, viz.,—1. To produce *aggregate velocity*, or a velocity which is the resultant of two or more components in the same path; and, 2. To produce *an aggregate path;* that is, to make a given point in a rigid body move in an assigned path by communicating certain motions to other points in that body.

It is seldom that one of these effects is produced without at the same time producing the other; but the classification of Mr Willis depends upon which of those two effects, even supposing them to occur together, is the practical object of the mechanism.

89. *Reduplication of Cords—Differential Windlass—Blocks, Sheaves, and Tackle.*—The axis C carries a larger barrel AE, and a smaller barrel DB, rotating as one piece with the angular velocity a_1 in the direction AE. The pulley or *sheave* FG has a weight W hung to its centre. A cord has one end made fast to and wrapped round the barrel AE; it passes from A under the sheave FG, and has the other end wrapped round and made fast to the barrel BD. Required the relation between the velocity of translation v_2 of W, and the angular velocity a_1 of the *differential barrel.*

In this case v_2 is an *aggregate velocity*, produced by the joint action of the two drivers AE and BD, transmitted by wrapping connectors to FG, and combined by that sheave so as to act on the follower W, whose motion is the same with that of the centre of FG.

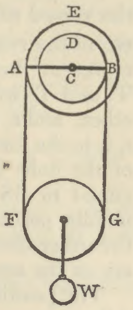


Fig. 28.

The velocity of the point F is $a_1 \cdot \overline{AC}$, *upward* motion being considered positive. The velocity of the point G is $-a_1 \cdot \overline{CB}$, *downward* motion being negative. Applying the principles of sect. 48, it appears that the instantaneous axis of the sheave FG is in the diameter FG, at the distance

$$\frac{\overline{FG}}{2} \cdot \frac{\overline{AC} - \overline{BC}}{\overline{AC} + \overline{BC}}$$

from the centre towards G; that the angular velocity of the sheave is

$$a_2 = a_1 \cdot \frac{\overline{AC} + \overline{BC}}{\overline{FG}};$$

and that, consequently, the velocity of its centre is

$$v_2 = a_2 \cdot \frac{\overline{FG}}{2} \cdot \frac{\overline{AC} - \overline{BC}}{\overline{AC} + \overline{BC}} = \frac{a_1(\overline{AC} - \overline{BC})}{2}, \quad . (51.)$$

or the *mean between the velocities of the two vertical parts of the cord.*

If the cord be fixed to the frame-work at the point B, instead of being wound on a barrel, the velocity of W is one-half of that of AF.

A case containing several sheaves is called a *block.* A *fall-block* is attached to a fixed point; a *running-block* is moveable to and from a fall-block, with which it is connected by two or more plies of a rope. The whole combination constitutes a *tackle* or *purchase.*

The two plies of a rope at opposite sides of a sheave in the fall-block have equal and opposite velocities. The two plies at opposite sides of a sheave in the running-block have velocities (as in the case of the sheave FG) differing equally in opposite directions from the velocity of the running-block.

One end of the rope is fastened either to the fall-block or the running-block. The other, or free end, is called the *fall.* Let v_1 be the velocity of the fall, v_2 that of the running-block; and let it be required to find their ratio; and let velocities towards the fall-block be positive, and from it negative.

Case 1. If the fastened end of the rope be attached to the fall-block its velocity is 0, and this also is the velocity of the first ply. The rope passes under a sheave in the running-block, so that the velocity of the second ply is $2v_2$. It then passes over a sheave in the fall-block; the velocity of the third ply is $-2v_2$; then under a sheave in the running-block; the velocity of the fourth ply is $4v_2$; and so on: the general law being this:—Let n be an *even* number, then

$$\left.\begin{array}{l} \text{The velocity of the } n^{th} \text{ ply} = nv_2; \\ \quad ,, \qquad (n+1) \cdot \text{ ply} = -nv_2 \\ = v_1, \text{ if the fall be the } (n+1)^{th} \text{ ply.} \end{array}\right\} \quad . (52.)$$

Case 2. If the fastened end of the rope be attached to the running-block, the velocity of the first ply is v_2; of the second, $-v_2$; of the third, $3v_2$; of the fourth $-3v_2$; and, generally, if n be an *odd* number,—

$$\left.\begin{array}{l} \text{Velocity of the } n^{th} \text{ ply} = nv_2 \\ \quad ,, \qquad (n+1)^{th} \text{ ply} = -nv_2 \\ = v_1, \text{ if the fall be the } (n+1)^{th} \text{ ply;} \end{array}\right\} \quad . (53.)$$

and generally,—

$$\frac{v_1}{v_2} = -n, \quad . \quad . \quad . \quad . \quad (54.)$$

where n is the *number of plies of rope by which the running-block hangs.*

The sheaves in a block are usually made all of the same diameter, and turn on a fixed pin, and they have, consequently, different angular velocities. But by making the diameter of each sheave proportional to the velocity, relatively to the block, of the ply of rope which it is to carry, the angular velocities of the sheaves in one block may be rendered equal, so that the sheaves may be made all in one piece, and may have journals turning in fixed bearings. This is called *White's tackle*, from the inventor.

For details and technical terms as to tackle and trains of tackle, see Ship-building.

90. *Differential Screw.*—On the same axis let there be two screws of the respective pitches p_1 and p_2, made in one piece, and rotating with the angular velocity a. Let this piece be called B. Let the first screw turn in a fixed nut C, and the second in a sliding nut A. The velocity of advance of B relatively to C is (according to sect. 47) ap_1; and of A relatively to B (according to sect. 73) $-ap_2$; hence the velocity of A relatively to C is

$$a(p_1 - p_2), \quad . \quad . \quad . \quad . \quad . \quad (55.)$$

being the same with the velocity of advance of a screw of the pitch $p_1 - p_2$. This combination, called *Hunter's*, or the *differential screw*, combines the strength of a large thread with the slowness of motion due to a small one.

91. *Epicyclic Trains.*—The term *epicyclic train* is used by Mr Willis to denote a train of wheels carried by an arm, and having certain rotations relatively to that arm, which itself rotates. The arm may either be driven by the wheels or assist in driving them. The comparative motions of the wheels and of the arm, and the *aggregate paths* traced by points in the wheels, are determined by the principles of the composition of rotations, and of the description of rolling curves, explained in sects. 42 to 46.

92. *Link Motion.*—Let S be the shaft of a steam-engine, O its axis, E_f the *forward eccentric*, suitably placed for

moving the slide-valve when the shaft rotates forwards, F its centre, OF its crank-arm, C_f its rod, E_b the *backward*

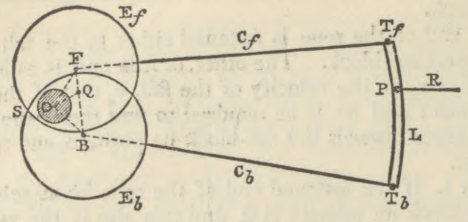


Fig. 29.

eccentric, suitably placed for moving the slide-valve when the shaft rotates backwards, B its centre, OB its crank-arm. C_b its rod. L is a long narrow box called the *link*, jointed at T_f and T_b to the eccentric rods; R is the valve-rod which works the slide-valve, jointed to P, a slider, which, either by moving L or R, or both, can be adjusted to any required position in the link. When P is at T_f, the valve is said to be in *full forward gearing*, being acted upon by E_f alone. When P is at T_b, the valve is said to be in *full backward gearing*, being acted upon by E_b alone.

When P is placed in an intermediate position, the valve has an aggregate motion due to the joint action of E_f and E_b. The most exact mode of determining that motion is to make a skeleton drawing of the apparatus in various positions; but an *approximation* to the motion of the valve may be obtained by joining FB, and taking Q, so that

$$\overline{T_fP} : \overline{T_bP} :: \overline{FQ} : \overline{BQ};$$

then the valve will move nearly as if it were worked by one eccentric, having its centre at Q.

93. *Parallel Motions—Exact.*—A *parallel motion* is a combination of turning pieces in mechanism designed to guide the motion of a reciprocating piece either exactly or approximately in a straight line, so as to avoid the friction which arises from the use of straight guides for that purpose.

Fig. 30 represents an exact parallel motion, first proposed, it is believed, by Mr Scott Russell.

The arm CD turns on the axis C, and is jointed at D to the middle of the bar ADB, whose length is double of that of CD, and one of whose ends B is jointed to a slider, sliding in straight guides along the line CB. Draw BE perpendicular to CB, cutting CD produced in E, then E is the instantaneous axis of the bar ADB; and the direction of motion of A is at every instant perpendicular to EA; that is, along the straight line AC*a*. While the stroke of A is AC*a* extending to equal distances on either side of C, and equal to twice the chord of the arc D*d*, the stroke of B is only equal to twice the sagitta; and thus A is guided through a comparatively long stroke by the sliding of B through a comparatively short stroke, and by rotatory motions at the joints C, D, B. (For details, see STEAM ENGINE.)

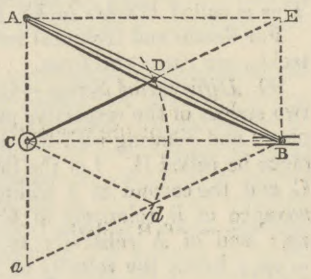


Fig. 30.

94. *Parallel Motion—Watt's Approximate.*—(See fig. 31.)—Let CT, *ct* be a pair of levers connected by a link T*t*, and oscillating about the axes C*c*, between the positions marked 1 and 3. Let the middle positions of the levers CT_2, ct_2 be parallel to each other. It is required to find a point P in the link T*t*, such that its middle position P_2, and its extreme positions P_1, P_3, shall be in the same straight line SS, perpendicular to CT_2, ct_2, and so to place the axes C, *c* on the lines CT_2, ct_2, that the path of P between the positions P_1, P_2, P_3, shall be as near as possible to a straight line.

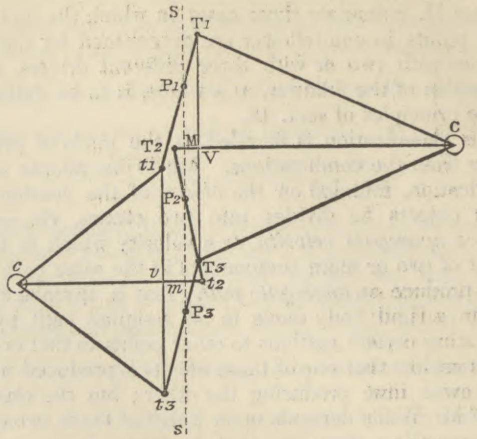


Fig. 31.

The axes C, *c* are to be so placed that the middle M of the versed sine VT_2, and the middle *m* of the versed sine vt_2, of the respective arcs whose equal chords $\overline{T_1T_3} = \overline{t_1t_3}$ represent the stroke, may each be in the line SS. Then T_1 and T_3 will be as far to one side of SS as T_2 is to the other, and t_1 and t_3 will be as far to the latter side of SS as t_2 is to the former; consequently, the two extreme positions of the links T_1t_1, T_3t_3 are parallel to each other, and inclined to SS at the same angle in one direction that the middle position of the link T_2t_2 is inclined to that line in the other direction; and the three intersections P_1, P_2, P_3, are at the same point on the link.

The position of the point P on the link is found by the following proportional equation:—

$$\left.\begin{array}{r}\overline{Tt} : \overline{PT} : \overline{Pt}\\ :: \overline{TV} + \overline{tv} : \overline{TV} : \overline{tv}\\ :: \overline{CM} + \overline{cm} : \overline{cm} : \overline{CM}\end{array}\right\} \quad . \quad (56.)$$

Suppose the axes C, *c* to be given, the line of stroke SS, and the length of stroke $L = T_1T_3 = t_1t_3$, and that it is required to find the dimensions of the levers and link. Let fall CM and $cm \perp$ SS; then

$$\left.\begin{array}{l}\overline{TV} = \dfrac{L^2}{8\,\overline{CM}}; \ tv = \dfrac{L^2}{8\,\overline{cm}};\\ \overline{CT} = \overline{CM} + \frac{1}{2}\overline{TV}; \ \overline{ct} = cm + \frac{1}{2}tv;\\ \overline{Tt} = \sqrt{\left\{L^2 + \dfrac{(\overline{TV} + \overline{tv})}{4}\right\}}\end{array}\right\} \quad . \quad (57.)$$

If C and *c* are at the same side of SS, the smaller of the two perpendiculars is to be treated as negative in the formulæ, and the difference of the versed sines used instead of their sum; and the point P will lie in the *prolongation* of the link beyond T*t* to the side of the longer lever. When the arcs of oscillation of the levers on either side of their middle positions do not exceed 20°, the intermediate portions of the path of P between P_1, P_2, and P_3, are near enough to a straight line for practical purposes; and that point may be used to guide a sliding piece, such as the piston-rod of a steam-engine, for which purpose this parallel motion was originally invented by Watt. (For details respecting the various modes of practically applying it, see STEAM ENGINE.)

CHAPTER II.—ON APPLIED DYNAMICS.

95. *Laws of Motion.*—The action of a machine in transmitting *force* and *motion* simultaneously, or performing *work*, is governed, in common with the phenomena of moving

bodies in general, by two "laws of motion," with respect to the proof of which, see DYNAMICS. They are as follows:—

LAW I. A body under the action of no force, or of mutually balanced forces, either remains at rest or moves in a straight line with an uniform velocity.

LAW II. The *deviation* of the motion of a given mass, caused in a given time by a given unbalanced force, takes place in the direction of the force, and is proportional to the magnitude of the force and the time during which it acts directly, and inversely to the mass.

(As to the determination of *deviations*, see sects. 25, 26, 27.)

The law of the *equality of action and reaction* is sometimes added as a "third law of motion;" but it is properly to be classed as a *law of force*, whether balanced or unbalanced; being equivalent to the statement that *every force is a pair of actions of equal magnitudes and opposite directions exerted mutually between a pair of bodies.*

96. *Comparison of Deviating Force with Gravity.*—A body's own weight,—that is, its tendency to approach the earth,—acting unbalanced on the body, produces deviation at a rate per second denoted by the symbol g, whose numerical value is as follows:—Let λ denote the latitude of the place, h its elevation above the mean level of the sea; $g_1 = 32{\cdot}169545$ feet per second, the value of g for $\lambda = 45^\circ$ and $h = 0$; and $R = 20887540^{ft.}\,(1 + 0{\cdot}00164 \cos 2\lambda)$, the earth's radius at the locality of observation. Then

$$g = g_1 \cdot (1 - 0{\cdot}00284 \cos 2\lambda) \cdot \left(1 - \frac{2h}{R}\right) \quad . \quad (58.)$$

For latitudes exceeding 45° it is to be borne in mind that $\cos 2\lambda$ is negative, and the terms containing it as their factor have their signs reversed.

For practical purposes connected with ordinary machines it is sufficiently accurate to assume

$$g = 32{\cdot}2 \text{ feet per second nearly.} \quad . \quad . \quad . \quad (59.)$$

If, then, a body of the weight w be deviated by an unbalanced force f expressed in *units of weight*, the deviation produced in a second will be

$$\frac{fg}{w} \quad . \quad . \quad . \quad (60.)$$

$\frac{w}{g}$ is sometimes called the *mass*, or *inertia* of the body.

97. *Deviating Forces Classed: Deflecting Force—Accelerating and Retarding Forces.*—The forces to be specially considered, in treating of machines as distinguished from structures, act upon bodies already in motion, and may be resolved into components and classed with reference to their directions as compared with the directions of motions of the bodies.

A force acting on a body in a direction at *right angles to its path*, produces *lateral deviation or deflection of the path* alone, without change of velocity. Such a force may be called a *deflecting force.*

A force acting in the direction of the body's path produces *acceleration* or *retardation* according as it acts *with* or *against* the motion of the body, but no deflection.

98. *Division of the Subject.*—On this classification of the deviating forces in machines is founded the following division of the subject of dynamics as applied to machines:—

Division I. Balanced forces in machines of uniform velocity.
Division II. Deflecting forces in such machines.
Division III. Working of machines of varying velocity.

DIVISION I.—BALANCED FORCES IN MACHINES OF UNIFORM VELOCITY.

99. *Application of Force to Mechanism.*—Forces are expressed in units of weight; and the unit most commonly employed in Britain is the *pound avoirdupois.* The action of a force applied to a body is always in reality distributed over some definite space, either a volume of three dimensions, or a surface of two. An example of a force distributed throughout a volume is the *weight* of the body itself, which acts on every particle, how small soever. The *pressure* exerted between two bodies at their surface of contact, or between the two parts of one body on either side of an ideal surface of separation, is an example of a force distributed over a surface. The mode of distribution of a force applied to a solid body requires to be considered when its stiffness and strength are treated of; but in questions respecting the action of a force upon a rigid body considered as a whole, the *resultant* of the distributed force, determined according to the principles of statics (*q. v.*), and considered as acting in a *single line* and applied at a *single point*, may, for the occasion, be substituted for the force as really distributed. Thus, the weight of each separate piece in a machine is treated as acting wholly at its *centre of gravity*, and each pressure applied to it as acting at a point called the *centre of pressure* of the surface to which the pressure is really applied.

100. *Forces applied to Mechanism Classed.*—If θ be the *obliquity* of a force F applied to a piece of a machine,—that is, the angle made by the direction of the force with the direction of motion of its point of application,—then, by the principles of statics (*q. v.*), F may be resolved into two rectangular components, viz.:—

$$\left.\begin{array}{l}\text{Along the direction of motion, } P = F \cdot \cos\theta \\ \text{Across the direction of motion, } Q = F \cdot \sin\theta\end{array}\right\} \quad (61.)$$

If the component along the direction of motion acts *with* the motion, it is called an *effort*; if *against* the motion, a *resistance.* The component *across* the direction of motion is a *lateral pressure;* the unbalanced lateral pressure on any piece, or part of a piece, is *deflecting force.* A lateral pressure may increase resistance by causing friction: the friction so caused acts against the motion, and is a resistance; but the lateral pressure causing it is not a resistance. Resistances are distinguished into *useful* and *prejudicial*, according as they arise from the useful effect produced by the machine or from other causes.

101. *Work.*—*Work* consists in moving against resistance. The work is said to be *performed*, and the resistance *overcome.* Work is measured by the product of the resistance into the distance through which its point of application is moved. The *unit of work* commonly used in Britain is a resistance of one pound overcome through a distance of one foot, and is called a *foot-pound.*

Work is distinguished into *useful work* and *prejudicial* or *lost work*, according as it is performed in producing the useful effect of the machine, or in overcoming prejudicial resistance.

102. *Energy—Potential Energy.*—*Energy* means *capacity for performing work.* The *energy of an effort*, or *potential energy*, is measured by the product of the effort into the distance through which its point of application is *capable* of being moved. The unit of energy is the same with the unit of work.

When the point of application of an effort *has been moved* through a given distance, energy is said to have been *exerted* to an amount expressed by the product of the effort into the distance through which its point of application has been moved.

103. *Variable Effort and Resistance.*—If an effort has different magnitudes during different portions of the motion of its point of application through a given distance, let each different magnitude of the effort P be multiplied by the length Δs of the corresponding portion of the path of the point of application; the sum

$$\Sigma \cdot P \Delta s \quad . \quad . \quad . \quad . \quad . \quad . \quad (62.)$$

is the whole energy exerted. If the effort varies by insensible gradations, the energy exerted is the integral or limit towards which that sum approaches continually as the divisions of the path are made smaller and more numerous, and is expressed by

$$\int \mathrm{P}ds. \quad . \quad . \quad . \quad . \quad . \quad . \quad (63.)$$

Similar processes are applicable to the finding of the work performed in overcoming a varying resistance.

104. *Dynamometer or Indicator.*—A dynamometer or indicator is an instrument which measures and records the energy exerted by an effort. It usually consists essentially, first, of a piece of paper moving with a velocity proportional to that of the point of application of the effort, and having a straight line marked on it parallel to its direction of motion, called the zero line; and secondly, of a spring acted upon and bent by the effort, and carrying a pencil whose perpendicular distance from the zero line, as regulated by the bending of the spring, is proportional to the effort. The pencil traces on the piece of paper a line such that its *ordinate* perpendicular to the zero line at a given point represents the effort P for the corresponding point in the path of the point of effort, and the *area between two ordinates* represent the energy exerted $\int \mathrm{P}ds$, for the corresponding portion of the path of the point of effort.

105. *Principle of the Equality of Energy and Work.*—From the first law of motion it follows, that in a machine whose pieces move with uniform velocities the efforts and resistances must balance each other. Now from the laws of statics (*q.v.*) it is known, that, in order that a system of forces applied to a system of connected points may be in equilibrio, it is necessary that the sum formed by putting together the products of the forces by the respective distances through which their points of application are capable of moving simultaneously, each along the direction of the force applied to it, shall be zero; products being considered positive or negative according as the direction of the forces and the possible motions of their points of application are the same or opposite.

In other words, the sum of the negative products is equal to the sum of the positive products. This principle, applied to a machine whose parts move with uniform velocities, is equivalent to saying, that in any given interval of time *the energy exerted is equal to the work performed.*

The symbolical expression of this law is as follows:—Let efforts be applied to one or to any number of points of a machine; let any one of these efforts be represented by P, and the distance traversed by its point of application in a given interval of time by ds; let resistances be overcome at one or any number of points of the same machine; let any one of these resistances be denoted by R, and the distance traversed by its point of application in the given interval of time by ds^1; then

$$\Sigma{\cdot}\mathrm{P}ds = \Sigma{\cdot}\mathrm{R}ds^1 \quad . \quad . \quad . \quad . \quad (64.)$$

The lengths ds, ds^1 are proportional to the velocities of the points to whose paths they belong, and the proportions of those velocities to each other are deducible from the construction of the machine by the principles of pure mechanism explained in chapter I.

106. *Efficiency.*—The *efficiency* of a machine is the ratio of the *useful* work to the *total* work, that is, to the energy exerted,—and is represented by

$$\frac{\Sigma{\cdot}\mathrm{R}_u ds^1}{\Sigma{\cdot}\mathrm{R}ds^1} = \frac{\Sigma{\cdot}\mathrm{R}_u ds^1}{\Sigma{\cdot}\mathrm{R}_u ds^1 + \Sigma{\cdot}\mathrm{R}_p ds^1} = \frac{\Sigma{\cdot}\mathrm{R}_u ds^1}{\Sigma{\cdot}\mathrm{P}ds} = \frac{\mathrm{U}}{\mathrm{E}} \quad (65.)$$

R_u being taken to represent useful, and R_p prejudicial resistances.

The more nearly the efficiency of a machine approaches to unity, the better is the machine.

107. *Power and Effect.*—The *power* of a machine is the energy exerted, and the *effect*, the useful work performed, in some interval of time of definite length, such as a second, a minute, an hour, or a day.

The unit of power, called conventionally a *horse-power*, is 550 foot-pounds per second, or 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour.

108. *Modulus of a Machine.*—In the investigation of the properties of a machine, the useful resistances to be overcome and the useful work to be performed are usually given. The prejudicial resistances are generally functions of the useful resistances of the weights of the pieces of the mechanism, and of their form and arrangement; and having been determined, they serve for the computation of the *lost* work, which, being added to the useful work, gives the expenditure of energy required. The result of this investigation, expressed in the form of an equation between the energy and the useful work, is called by Mr Moseley the *modulus* of the machine. The general form of the modulus of a machine may be expressed thus

$$\mathrm{E} = \mathrm{U} + \varphi(\mathrm{U}, \mathrm{A}) + \psi(\mathrm{A}), \quad . \quad . \quad . \quad (66.)$$

where A denotes some quantity or set of quantities depending on the form, arrangement, weight, and other properties of the mechanism. Mr Moseley, however, has pointed out that in most cases this equation takes the much more simple form of

$$\mathrm{E} = (1 + \mathrm{A})\mathrm{U} + \mathrm{B}, \quad . \quad . \quad . \quad . \quad (67.)$$

where A and B are *constants*, depending on the form, arrangement, and weight of the mechanism. The efficiency corresponding to the last equation is

$$\frac{\mathrm{U}}{\mathrm{E}} = \frac{1}{1 + \mathrm{A} + \frac{\mathrm{B}}{\mathrm{U}}}. \quad . \quad . \quad . \quad . \quad (68.)$$

109. *Trains of Mechanism.*—In applying the preceding principles to a train of mechanism, it may either be treated as a whole, or it may be considered in sections consisting of single pieces, or of any convenient portion of the train; each section being treated as a machine driven by the effort applied to it and energy exerted upon it through its line of connection with the preceding section, performing useful work by driving the following section, and losing work by overcoming its own prejudicial resistances.

It is evident that *the efficiency of the whole train is the product of the efficiencies of its sections.*

110. *Rotating Pieces: Couples of Forces.*—It is often convenient to express the energy exerted upon, and the work performed by, a turning piece in a machine, in terms of the *moment* of the *couples of forces* acting on it, and of the angular velocity. A *couple* of forces consists of two forces equal in magnitude and opposite in direction, but not acting in the same line (as P_1, P_2, in fig. 32). The perpendicular distance between the lines of action of the forces is the *leverage* or *arm* of the couple (as $\overline{\mathrm{AB}}$). The tendency of a couple is to turn the body to which it is applied about an axis perpendicular to the plane containing the couple and its arm, and the magnitude of that tendency, called the *moment* of the couple, is measured by the product of the common magnitude of the forces into the length of their arm. That is to say, let $\mathrm{P} = \mathrm{P}_1 = \mathrm{P}_2$, $\overline{\mathrm{AB}} = r$; then the movement is

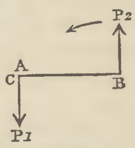


Fig. 32.

$$\mathrm{M} = \mathrm{P}r. \quad . \quad . \quad . \quad . \quad . \quad (69.)$$

The ordinary British unit of moment is a *foot-pound;* but it is to be remembered that this is a foot-pound of a different sort from the unit of energy and work.

If a force be applied to a turning piece in a line not passing through its axis, the axis will press against its bearings with an equal and parallel force, and the equal and opposite reaction of the bearings will constitute, together with the first-mentioned force, a couple whose arm is the perpendicular distance from the axis to the line of action of the first force.

A couple is said to be *right* or *left handed* with reference to the observer, according to the direction in which it tends to turn the body, and is a *driving* couple, or a *resisting* couple according as its tendency is with or against that of the actual rotation.

Let dt be an interval of time, a the angular velocity of the piece; then adt is the angle through which it turns in the interval dt, and $ds=vdt=radt$ is the distance through which the point of application of the force moves. Let P represent an effort, so that $\mathrm{P}r$ is a driving couple, then

$$\mathrm{P}ds=\mathrm{P}vdt=\mathrm{P}radt=\mathrm{M}adt \quad . \ . \ . \quad (70.)$$

is the energy exerted by the couple M in the interval dt; and a similar equation gives the work performed in overcoming a resisting couple. When several couples act on one piece, the resultant of their moments is to be multiplied by the common angular velocity of the whole piece.

111. *Reduction of Forces to a given Point, and of Couples to the Axis of a given Piece.*—In computations respecting machines it is often convenient to substitute for a force applied to a given point, or a couple applied to a given piece, the *equivalent* force or couple applied to some other point or piece; that is to say, the force or couple, which, if applied to the other point or piece, would exert equal energy or employ equal work. The principles of this reduction are, that the ratio of the given to the equivalent force is the reciprocal of the ratio of the velocities of their points of application; and the ratio of the given to the equivalent couple is the reciprocal of the ratio of the angular velocities of the pieces to which they are applied.

These velocity-ratios are known by the construction of the mechanism, and are independent of the absolute speed.

112. *Balanced Lateral Pressure of Guides and Bearings.*—The most important part of the lateral pressure on a piece of mechanism is the reaction of its guides, if it is a sliding piece, or of the bearings of its axis, if it is a turning piece; and the balanced portion of this reaction is equal and opposite to the resultant of all the other forces applied to the piece, its own weight included. There may or may not be an unbalanced component in this pressure, due to deviated motion. Its laws will be considered in the sequel.

113. *Friction—Unguents.*—The most important kind of resistance in machines is the *friction* or *rubbing resistance* of surfaces which slide over each other. The *direction* of the resistance of friction is opposite to that in which the sliding takes place. Its *magnitude* is the product of the *normal pressure* or force which presses the rubbing surfaces together in a direction perpendicular to themselves, into a specific constant already mentioned in part I., sect. 14, as the *coefficient of friction*, which depends on the nature and condition of the surfaces and of the unguent, if any, with which they are covered. The *total pressure* exerted between the rubbing surfaces is the resultant of the normal pressure and of the friction, and its *obliquity*, or inclination to the common perpendicular of the surfaces, is the *angle of repose* formerly mentioned in sect. 14, whose tangent is the coefficient of friction. Thus, let N be the normal pressure, R the friction, T the total pressure, f the coefficient of friction, and ϕ the angle of repose; then

$$\left.\begin{array}{c} f=\tan\phi\,; \\ \mathrm{R}=f\mathrm{N}=\mathrm{N}\tan\phi=\mathrm{T}\sin\phi\,; \end{array}\right\} \quad \cdot \ \cdot \quad (71.)$$

Experiments on friction have been made by Coulomb, Vince, Rennie, Wood, D. Rankine, and others. The most complete and elaborate experiments are those of Morin, published in his *Notions Fondamentales de Mécanique*, and republished in Britain in the works of Moseley and Gordon. The following is an exceedingly condensed abstract of the most important results, as regards machines, of these experiments:—

Surfaces.	*f.*
Wood on wood, dry	0·25 to 0·5
Do., soaped	0·2
Metals on oak, dry	0·5 to 0·6
Do., wet	0·24 to 0·26
Do., soaped	0·2
Do. on elm, dry	0·2 to 0·25
Hemp on oak, dry	0·53
Do., wet	0·33
Leather on oak, wet or dry	0·27 to 0·35
Leather on metals, dry	0·56
Do., wet	0·36
Do., greasy	0·23
Do., oiled	0·15
Metals on metals, dry	0·15 to 0·2
Do., wet	0·30
Smooth Surfaces with Unguents—	
Occasionally greased	0·07 to 0·08
Well greased	0·05
Do., best results	0·03 to 0·036

It is to be understood that the above-stated law of friction is true for dry surfaces, only when the pressure is not sufficient to indent or abrade the surfaces; and for greased surfaces, when the pressure is not sufficient to force out the unguent from between the surfaces. If the proper limit be exceeded, the friction increases more rapidly than in the simple ratio of the normal pressure.

The limit of pressure for unguents diminishes as the speed increases; and the following are some of its approximate values as inferred from the results of experience in railway, locomotive, and carriage axles:—

Velocity of rubbing in feet per second	1	$2\frac{1}{3}$	5
Intensity of normal pressure per lb. per square inch of surface	392	224	140

In pivots, the intensity of the pressure is usually fixed at about one ton per square inch.

Unguents should be comparatively thick for heavy pressures, that they may resist being forced out; and comparatively thin for light pressures, that their viscidity may not add to the resistance.

Unguents are of three classes, viz.:—

1. *Fatty*; consisting of animal or vegetable fixed oils, such as tallow, lard, lard-oil, seal-oil, whale-oil, olive-oil. *Drying* oils, which absorb oxygen and harden, are obviously unfit for unguents.

2. *Soapy*; composed of fatty oil, alkali, and water. The best grease of this class should not contain more than about 25 or 30 per cent. of water; bad kinds contain 40 or 50 per cent. The additional water diminishes the cost, but spoils the unguent.

3. *Bituminous*; composed of solid and liquid mineral compounds of hydrogen and carbon.

114. *Work of Friction—Moment of Friction.*—The work performed in an unit of time in overcoming the friction of a pair of surfaces is the product of the friction by the velocity of sliding of the surfaces over each other, if that is the same throughout the whole extent of the rubbing surfaces. If that velocity is different for different portions of the rubbing surfaces, the velocity of each portion is to be multiplied by the friction of that portion, and the results summed or integrated.

When the relative motion of the rubbing surfaces is one of rotation, the work of friction in an unit of time, for a portion of the rubbing surfaces at a given distance from the axis of rotation, may be found by multiplying together the friction of that portion, its distance from the axis, and the angular velocity. The product of the force of friction by the distance at which it acts from the axis of rotation is called the *moment of friction*. The total moment of friction of a pair of rotating rubbing surfaces is the sum or integral of the moments of friction of their several portions.

To express this symbolically, let du represent the area of a portion of a pair of rubbing surfaces at the distance r from the axis of their relative rotation; p the intensity of the normal pressure at du per unit of area; and f the coefficient of friction. Then the moment of friction of du is

$$\left.\begin{array}{l} \qquad fprdu, \\ \text{the total moment of friction,} \\ \qquad f\int pr\cdot du; \\ \text{and the work performed in an unit of} \\ \text{time in overcoming friction, when the} \\ \text{angular velocity is } a, \\ \qquad af\int pr\cdot du. \end{array}\right\} \quad . \quad . \quad . \quad (72.)$$

It is evident that the moment of friction, and the work lost by being performed in overcoming friction, are less in a rotating piece as the bearings are of smaller radius. But a limit is put to the diminution of the radii of journals and pivots by the conditions of durability and of proper lubrication stated in sect. 113, and also by conditions of strength and stiffness.

115. *Total Pressure between Journal and Bearing.*—A single piece rotating with an uniform velocity has four mutually balanced forces applied to it: the effort exerted on it by the piece which drives it; the resistance of the piece which follows it,—which may be considered for the purposes of the present question as useful resistance; its weight, and the reaction of its own cylindrical bearings. There are given the following data:—

The direction of the effort.
The direction of the useful resistance.
The weight of the piece and the direction in which it acts.
The magnitude of the useful resistance.
The radius of the bearing r.
The angle of repose φ, corresponding to the friction of the journal on the bearing.

And there are required—

The direction of the reaction of the bearing.
The magnitude of that reaction.
The magnitude of the effort.

Let the useful resistance and the weight of the piece be compounded by the principles of statics into one force, and let this be called *the given force*.

The directions of the effort and of the given force are either parallel or meet in a point. If they are parallel, the direction of the reaction of the bearing is also parallel to them; if they meet in a point, the direction of the reaction traverses the same point.

Also, let AAA, fig. 33, be a section of the bearing, C its axis; then the direction of the reaction, at the point where it intersects the circle AAA, must make the angle ϕ with the radius of that circle; that is to say, it must be a line such as PT touching the smaller circle BB, whose radius is $r\cdot\sin\phi$. The side on which it touches that circle is determined by the fact that the obliquity of the reaction is such as to oppose the rotation.

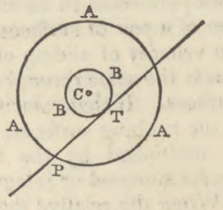


Fig. 33.

Thus is determined the direction of the reaction of the bearing; and the magnitude of that reaction and of the effort are then found by the principles of the equilibrium of three forces, already stated in part I., sect. 8, and proved in the article STATICS.

The work lost in overcoming the friction of the bearing is the same with that which would be performed in overcoming at the circumference of the small circle BB a resistance equal to the whole pressure between the journal and bearing.

In order to diminish that pressure to the smallest possible amount, the effort, and the resultant of the useful resistance, and the weight of the piece (called above, the "given force"), ought to be opposed to each other as directly as is practicable consistently with the purposes of the machine.

116. *Frictions of Pivots and Collars.*—When a shaft is acted upon by a force tending to shift it lengthways, that force must be balanced by the reaction of a bearing against a *pivot* at the end of the shaft; or, if that be impossible, against one or more *collars*, or rings *projecting* from the body of the shaft. The bearing of a pivot is called a *step* or *footstep*. Pivots require great hardness, and are usually made of steel. The *flat* pivot is a cylinder of steel having a plane circular end as a rubbing surface. Let N be the total pressure sustained by a flat pivot of the radius r; if that pressure be uniformly distributed, which is the case when the rubbing surfaces of the pivot and its step are both true planes, the *intensity* of the pressure is

$$p=\frac{\text{N}}{2\pi r^2}, \quad . \quad . \quad . \quad . \quad . \quad (73.)$$

and introducing this value into equation 72, the *moment of friction of the flat pivot* is found to be

$$\frac{2}{3}f\,\text{N}r, \quad . \quad . \quad . \quad . \quad . \quad (74.)$$

or two-thirds of that of a cylindrical journal of the same radius under the same normal pressure.

The friction of a *conical* pivot exceeds that of a flat pivot of the same radius, and under the same pressure, in the proportion of the side of the cone to the radius of its base.

The moment of friction of a *collar* is given by the formula—

$$\frac{2}{3}f\,\text{N}\frac{r^3-r'^3}{r^2-r'^2}, \quad . \quad . \quad . \quad . \quad (75.)$$

where r is the external, and r' the internal radius.

In the *cup and ball* pivot the end of the shaft and the step present two recesses facing each other, into which are fitted two shallow cups of steel or hard bronze. Between the concave spherical surfaces of those cups is placed a steel ball, being either a complete sphere, or a lens having convex surfaces of a somewhat less radius than the concave surfaces of the cups. The moment of friction of this pivot is at first almost inappreciable from the extreme smallness of the radius of the circles of contact of the ball and cups; but as they wear, that radius and the moment of friction increase.

It appears that the rapidity with which a rubbing surface wears away is proportional, jointly to the friction and to the velocity, or nearly so. Hence the pivots already mentioned wear unequally at different points, and tend to alter their figures. Mr Schiele has invented a pivot which preserves its original figure by wearing equally at all points in a direction parallel to its axis. The following are the principles on which this equality of wear depends:—

The rapidity of wear of a surface measured in an *oblique* direction is to the rapidity of wear measured normally as the secant of the obliquity is to unity. Let OX (fig. 34) be the axis of a pivot, and let RPC be a portion of a curve such, that at any point P the secant of the obliquity to the normal of the curve of a line parallel to the axis is inversely proportional to the ordinate PY, to which the velocity of P is proportional. The rotation of that curve round OX will generate the form of pivot required. Now, let PT be a tangent to the curve at P, cutting OX in

T; $\overline{PT}=\overline{PY}\times$ *secant obliquity*, and this is to be a constant quantity; hence the curve is that known as the *tractory* of the straight line OX, in which $\overline{PT}=\overline{OR}=$constant. This curve is described by having a fixed straight edge parallel to OX, along which slides a slider carrying a pin whose centre is T. On that pin turns an arm, carrying at the point P a tracing-point, pencil, or pen. Should the pen have a nib of two jaws, like those of an ordinary drawing-pen, the plane of the jaws must pass through PT. Then, while T is slid along the axis from O towards X, P will be drawn after it from R towards C along the tractory. This curve, being an asymptote to its axis, is capable of being indefinitely prolonged towards X; but in designing pivots it should stop before the angle PTY becomes less than the angle of repose of the rubbing surfaces, otherwise the pivot will be liable to stick in its bearing.

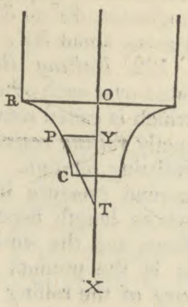


Fig 34.

The moment of friction of "Schiele's Anti-friction Pivot," as it is called, is equal to that of a cylindrical journal of the radius $\overline{OR}=\overline{PT}$ the constant tangent, under the same pressure

117. *Friction of Teeth.*—Let N be the normal pressure exerted between a pair of teeth of a pair of wheels; *s* the total distance through which they slide upon each other; *n* the number of pairs of teeth which pass the plane of axis in a unit of time. Then

$$nfNs \quad . \quad . \quad . \quad . \quad . \quad . \quad (76.)$$

is the work lost in unity of time by the friction of the teeth. The sliding *s* is composed of two parts, which take place during the approach and recess respectively. Let those be denoted by s_1 and s_2, so that $s=s_1+s_2$. In sec. 61 the *velocity* of sliding at any instant has been given, viz., $u=c\,(a_1+a_2)$, where u is that velocity, c the distance $\overline{TI}$ at any instant from the point of contact of the teeth to the pitch-point, and a_1, a_2 the respective angular velocities of the wheels.

Let v be the common velocity of the two pitch-circles, r_1, r_2 their radii; then the above equation becomes

$$u=cv\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$$

To apply this to involute teeth, let c_1 be the length of the approach; c_2 that of the recess; u_1 the *mean* velocity of sliding during the approach, u_2 that during the recess. Then

$$u_1=\frac{c_1v}{2}\left(\frac{1}{r_1}+\frac{1}{r_2}\right);\ u_2=\frac{cv}{2}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$$

also, let θ be the obliquity of the action; then the times occupied by the approach and recess are respectively

$$\frac{c_1}{v\cos\theta},\ \frac{c_2}{v\cos\theta};$$

giving, finally, for the length of sliding between each pair of teeth,

$$s=s_1+s_2=\frac{c_1^{\,2}+c_2^{\,2}}{2\cos\theta}\left(\frac{1}{r_1}+\frac{1}{r_2}\right). \quad . \quad . \quad (77.)$$

which, being substituted in equation 76, gives the work lost in a unit of time by the friction of involute teeth. This result, which is exact for involute teeth, is approximately true for teeth of any figure.

For inside gearing, if r_1 be the less radius and r_2 the greater, $\frac{1}{r_1}-\frac{1}{r_2}$ is to be substituted for $\frac{1}{r_1}+\frac{1}{r_2}$.

118. *Friction of Cords and Belts.*—A flexible band, such as a cord, rope, belt, or strap, may be used either to exert an effort or a resistance upon a pulley round which it wraps. In either case the tangential force, whether effort or resistance, exerted between the band and the pulley is their mutual friction, caused by and proportional to the normal pressure between them.

Let T_1 be the tension of the free part of the band at that side *towards* which it tends to draw the pulley, or *from* which the pulley tends to draw it; T_2 the tension of the free part at the other side; T the tension of the band at any intermediate point of its arc of contact with the pulley; θ the ratio of the length of that arc to the radius of the pulley; $d\theta$ the ratio of an indefinitely small element of that arc to the radius; $F=T_1-T_2$ the total friction between the band and the pulley; dF the elementary portion of that friction due to the elementary arc $d\theta$; f the coefficient of friction between the materials of the band and pulley.

Then, according to a principle proved in the articles STATICS and ARCH, it is known that the normal pressure at the elementary arc $d\theta$ is $Td\theta$, T being the mean tension of the band at that elementary arc; consequently the friction on that arc is $dF=fTd\theta$. Now that friction is also the difference between the tensions of the band at the two ends of the elementary arc, or $dT=dF=fTd\theta$; which equation being integrated throughout the entire arc of contact, gives the following formulæ:—

$$\left.\begin{aligned}&\text{hyp. log}\ \frac{T_1}{T_2}=f\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .\\ &\frac{T_1}{T_2}=e^{f\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .\\ &F=T_1-T_2=T_1\left(1-e^{-f\theta}\right)=T_2\left(e^{f\theta}-1\right)\end{aligned}\right\}(78.)$$

When a belt connecting a pair of pulleys has the tensions of its two sides originally equal, the pulleys being at rest; and when the pulleys are next set in motion, so that one of them drives the other by means of the belt; it is found that the advancing side of the belt is exactly as much tightened as the returning side is slackened; so that the *mean* tension remains unchanged. Its value is given by this formula—

$$\frac{T_1+T_2}{2}=\frac{e^{f\theta}+1}{2\left(e^{f\theta}-1\right)}, \quad . \quad . \quad . \quad (79.)$$

which is useful in determining the original tension required to enable a belt to transmit a given force between two pulleys.

The equations 78 and 79 are applicable to a kind of *brake* called a *friction-strap*, used to stop or moderate the velocity of machines by being tightened round a pulley. The strap is usually of iron, and the pulley of hard wood.

Let a denote the arc of contact expressed in *turns and fractions of a turn*; then

$$\left.\begin{aligned}&\theta=6{\cdot}2832a\\ &e^{f\theta}=\text{number whose common logarithm is } 2{\cdot}7288fa\end{aligned}\right\}(80.)$$

119. *Stiffness of Ropes.*—Ropes offer a resistance to being bent, and when bent, to being straightened again, which arises from the mutual friction of their fibres. It increases with the sectional area of the rope, and is inversely proportional to the radius of the curve into which it is bent.

The *work lost* in pulling a given length of rope over a pulley is found by multiplying the length of the rope in feet by its stiffness in pounds; that stiffness being the excess of the tension at the leading side of the rope above that at the following side, which is necessary to bend it into a curve fitting the pulley, and then to straighten it again.

The following empirical formulæ for the stiffness of hempen ropes have been deduced by Morin from the experiments of Coulomb:—

Let F be the stiffness in pounds avoirdupois; d the diameter of the rope in inches, $n=48d^2$ for white ropes, $35d^2$ for tarred ropes; r the *effective* radius of the pulley in inches; T the tension in pounds. Then

$$\left.\begin{aligned}\text{For white ropes, } \mathrm{F} &= \frac{n}{r}(0\cdot0012 + 0\cdot001026n + 0\cdot0012\mathrm{T})\\ \text{For tarred ropes, } \mathrm{F} &= \frac{n}{r}(0\cdot006 + 0\cdot001392n + 0\cdot00168\mathrm{T})\end{aligned}\right\} \quad (81.)$$

120. *Friction-Couplings.*—Friction is useful as a means of communicating motion where sudden changes either of force or velocity take place; because, being limited in amount, it may be so adjusted as to limit the forces which strain the pieces of the mechanism within the bounds of safety. Amongst contrivances for effecting this object are *friction-cones.* A rotating shaft carries upon a cylindrical portion of its figure a wheel or pulley turning loosely on it, and consequently capable of remaining at rest when the shaft is in motion. This pulley has fixed to one side, and concentric with it, a short frustum of a hollow cone. At a small distance from the pulley the shaft carries a short frustum of a solid cone accurately turned to fit the hollow cone. This frustum is made always to turn along with the shaft by being fitted on a square portion of it, or by means of a rib and groove, or otherwise; but is capable of a slight longitudinal motion, so as so be pressed into, or withdrawn from, the hollow cone by means of a lever. When the cones are pressed together or engaged, their friction causes the pulley to rotate along with the shaft; when they are disengaged, the pulley is free to stand still. The angle made by the sides of the cones with the axis should not be less than the angle of repose. In the *friction-clutch,* a pulley loose on a shaft has a hoop or gland made to embrace it more or less tightly by means of a screw: this hoop has short projecting arms or ears. A fork or *clutch* rotates along with the shaft, and is capable of being moved longitudinally by a handle. When the clutch is moved towards the hoop, its arms catch those of the hoop, and cause the hoop to rotate and to communicate its rotation to the pulley by friction. There are many other contrivances of the same class, but the two just mentioned may serve for examples.

121. *Heat of Friction—Unguents.*—The work lost in friction is employed in producing heat. This fact is very obvious, and has been known from a remote period; but the *exact* determination of the proportion of the work lost to the beat produced, and the experimental proof that that proportion is the same under all circumstances, and with all materials, solid, liquid, and gaseous, are recent achievements of Mr Joule. The quantity of work which produces a British unit of heat (or so much heat as elevates the temperature of one pound of pure water, at or near ordinary atmospheric temperatures, by one degree of Fahrenheit) is 772 foot-pounds. This constant, now designated as "Joule's Equivalent," is the principal experimental datum of the science of THERMODYNAMICS, which treats of the relations between heat and mechanical work.

The heat produced by friction, when moderate in amount, is useful in softening and liquifying thick unguents; but when excessive it is prejudicial, by decomposing the unguents, and sometimes even by softening the metal of the bearings, and raising their temperature so high as to set fire to neighbouring combustible matters.

Excessive heating is prevented by a constant and copious supply of a good unguent. The elevation of temperature produced by the friction of a journal is sometimes used as an experimental test of the quality of unguents. When the velocity of rubbing is about 4 or 5 feet per second, the elevation of temperature has been found by some recent experiments to be, with good fatty and soapy unguents, 40° to 50° Fahrenheit; with good mineral unguents, about 30°.

122. *Rolling Resistance.*—By the rolling of two surfaces over each other without sliding, a resistance is caused which is called sometimes "rolling friction," but more correctly *rolling resistance.* It is of the nature of a *couple,* resisting rotation. Its *moment* is found by multiplying the normal pressure between the rolling surfaces by an *arm,* whose length depends on the nature of the rolling surfaces, and the work lost in a unit of time in overcoming it is the product of its moment by the *angular velocity* of the rolling surfaces relatively to each other. The following are approximate values of the arm in *decimals of a foot*:—

Oak upon oak..................	0·006	(Coulomb.)
Lignum vitæ on oak...........	0·004	(Do)
Cast-iron on cast-iron........	0·002	(Tredgold.)

123. *Reciprocating Forces—Stored and Restored Energy.*—When a force acts on a machine alternately as an effort and as a resistance, it may be called a *reciprocating force.* Of this kind is the weight of any piece in the mechanism whose centre of gravity alternately rises and falls; for during the rise of the centre of gravity that weight acts as a resistance, and energy is employed in lifting it to an amount expressed by the product of the weight into the vertical height of its rise; and during the fall of the centre of gravity the weight acts as an effort, and exerts in assisting to perform the work of the machine an amount of energy exactly equal to that which had previously been employed in lifting it. Thus that amount of energy is not lost, but has its operation deferred; and it is said to be *stored* when the weight is lifted, and *restored* when it falls.

In a machine of which each piece is to move with an uniform velocity, if the effort and the resistance be constant, the weight of each piece must be balanced on its axis, so that it may produce lateral pressure only, and not act as a reciprocating force. But if the effort and the resistance be alternately in excess, the uniformity of speed may still be preserved by so adjusting some moving weight in the mechanism, that when the effort is in excess it may be lifted, and so balance and employ the excess of effort; and that when the resistance is in excess it may fall, and so balance and overcome the excess of resistance; thus *storing* the periodical excess of energy, and *restoring* that energy to perform the periodical excess of work.

Other forces besides gravity may be used as reciprocating forces for storing and restoring energy; for example, the elasticity of a spring or of a mass of air.

In most of the delusive machines commonly called "perpetual motions," of which so many are patented in each year, and which are expected by their inventors to perform work without receiving energy, the fundamental fallacy consists in an expectation that some reciprocating force shall restore more energy than it has been the means of storing.

DIVISION II.—DEFLECTING FORCES.

124. *Deflecting Force for Translation in a Curved Path.*—If a body have a motion of translation with the velocity v, so that each point in it moves in a curved path of the radius ρ, then, as we have already seen (sect. 27.) the rate of deflection of that body's motion in unity of time, which is common to all its points, is expressed by

$\frac{v^2}{\rho} = \rho\alpha^2$, if α be substituted for $\frac{d\theta}{dt}$, the expression in equation 3 for the angular velocity of deflection.

To produce this deviation the body must (according to sect. 96, equation 60) be acted upon by a lateral pressure at right angles to, and towards the centre of curvature of its path, whose magnitude is given by the equation—

$$F = \frac{wv^2}{g\rho} = \frac{w\rho\alpha^2}{g}, \quad . \quad . \quad . \quad . \quad (82.)$$

where w is the weight of the body, and g the deviation produced by gravity in a second (see sect. 96); and as this total deflecting force F is the resultant of deflecting forces acting upon each particle of the body and proportional respectively to the masses of the particles, its line of action must traverse the centre of gravity of the body.

In machinery, deflecting force is supplied by the tenacity of some piece, such as a crank, which guides the deflected body in its curved path, and is *unbalanced*, being employed in producing deflection, and not in balancing another force.

125. *Centrifugal Force.*—The deflecting body reacts upon the guiding body with a lateral pressure equal and opposite to the deflecting force, and called the *centrifugal force*, because of its arising from the tendency of the deflected body to move in a straight line, and so to fly from the centre of its curved path; and also because of its tending to pull the guiding body away from that centre.

In fact, as has been stated in section 95, every force is a pair of equal and opposite actions between a pair of bodies; and *deflecting force* and *centrifugal force* are but two different names for the same force, applied to it according as its action on the deflected body or on the guiding body is under consideration for the time. The action on the deflected body is to produce deflection at a rate proportional to the force; the action on the guiding body is to strain it and the framework which carries it, to be balanced by the stiffness which resists that strain, and to cause increased friction at rubbing surfaces. Hence it appears that the action of centrifugal force is in general prejudicial, and that it is desirable in well-designed machinery to diminish it as much as possible.

126. *Rectangular Resolution of Centrifugal Force.*—For convenience in mathematical investigation, centrifugal force may be resolved into rectangular components as follows:—In fig. 35 let O be the centre of curvature and ρ the radius of the path of the centre of gravity of the body w, whose angular velocity of deflection is α. Let OX, OY be a pair of rectangular axes in the plane of motion of w, and x, y perpendiculars let fall from the centre of gravity of w upon these axes. It is evident that the centrifugal force exerted by w upon an axis at O may be resolved into two rectangular components, F_x, F_y, parallel to OX, OY respectively, and bearing to each other and to the whole centrifugal force F the following proportions:—

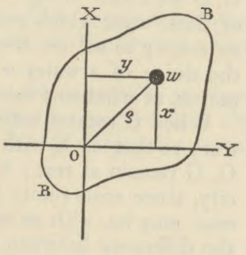


Fig. 35.

$$\left.\begin{array}{l} F : F_x : F_y \\ \quad :: \rho : x : y; \\ \text{consequently their values are—} \\ F_x = \dfrac{wx\alpha^2}{g};\ F_y = \dfrac{wy\alpha^2}{g}. \end{array}\right\} \quad . \quad . \quad . \quad (83.)$$

127. *Centrifugal Force of a Rotating Body.*—Let a body of any figure BB rotate about the axis of rotation O, perpendicular to the plane XOY of the rectangular axes of co-ordinates before-mentioned. Let W be the entire weight of the body; let α be its angular velocity of rotation; this, as shown in section 38, is also the angular velocity of deflection of each particle of the body in its revolution round the axis. Conceive the body to be divided into an indefinite number of indefinitely small particles; denote one of them by dW, and let its co-ordinates be x and y. The components of the centrifugal force exerted by it on the axis O are respectively

$$\frac{x\alpha^2 dW}{g} \text{ and } \frac{y\alpha^2 dW}{g};$$

and the components of the centrifugul force exerted by the *whole body* on that axis, being the sums or integrals of the centrifugal forces exerted by all the particles, are expressed by—

$$F_x = \frac{\alpha^2}{g}\int x \cdot dW, \text{ and } F_y = \frac{\alpha^2}{g}\int y \,.\, dW.$$

Now, by the properties of the centre of gravity (for which see STATICS), if x_1 and y_1 be the co-ordinates of the centre of gravity of the body BB,

$$\int x \cdot dW = x_1 W;\ \int y \cdot dW = y_1 W;$$

consequently

$$F_x = \frac{Wx_1\alpha^2}{g};\ F_y = \frac{Wy_1\alpha^2}{g}; \quad . \quad . \quad (84.)$$

being precisely the same values which were found in section 126, equation 83, for the components of the centrifugal force due to a circular translation with a radius equal to the distance of the centre of gravity of the body from the axis of rotation.

Hence *the centrifugal force exerted by a rotating body on its axis of rotation, is the same in magnitude as if the mass of the body were concentrated at its centre of gravity, and acts in a plane passing through the axis of rotation and the centre of gravity of the body.*

The particles of a rotating body exert centrifugal forces on each other, which strain the body, and tend to tear it asunder; but these forces balance each other, and do not affect the resultant centrifugal force exerted on the axis of rotation.[1]

If the axis of rotation traverses the centre of gravity of the body, the centrifugal force exerted on that axis is nothing.

Hence, unless there be some reason to the contrary, each piece of a machine should be balanced on its axis of rotation; otherwise the centrifugal force will cause strains, vibration, and increased friction, and a tendency of the shafts to jump out of their bearings.

128. *Centrifugal Couples of a Rotating Body.*—Besides the tendency (if any) of the combined centrifugal forces of the particles of a rotating body to *shift* the axis of rotation, they may also tend to *turn* it out of its original direction. The latter tendency is called a *centrifugal couple.*

To determine its amount, or the amount of its components, let z denote the distance (positive towards, negative from, the spectator), of any given particle dW from the plane XOY. Then the tendencies of the centrifugal force of dW to turn the axis of rotation O towards the right hand, about OX, is the moment of the couple, $-\dfrac{zy\alpha^2 dW}{g}$, and about OY, the moment of the couple, $+\dfrac{zx\alpha^2 dW}{g}$; and by integrating those expressions, the centrifugal couples of the whole body are found to be respectively—

---

[1] This is a particular case of a more general principle, that *the motion of the centre of gravity of a body is not affected by the mutual actions of its parts*; for the proof of which see DYNAMICS.

$$M_x = -\frac{a^2}{g} \cdot \int zy \cdot dW, \qquad M_y = -\frac{a^2}{g} \cdot \int zx \cdot dW. \qquad \ldots (85.)$$

A *permanent* or *principal axis* of rotation is one for which each of the centrifugal couples, as well as the centrifugal force, is nothing, and is the only kind of axis about which a body not acted upon by an external force can steadily rotate. It can be proved that every body, of what shape soever, has *at least* three permanent axes at right angles to each other.

It is essential to the steady motion of every rapidly rotating piece in a machine, that its axis of rotation should not merely traverse its centre of gravity, but should be a permanent axis; for otherwise the centrifugal couples will increase friction, produce oscillation of the shaft, and tend to make it leave its bearings.

The principles of this and the preceding section are those which regulate the adjustment of the weight and position of the *counterpoises* which are placed between the spokes of the driving-wheels of locomotive engines.

129. *Revolving Pendulum—Governors.*—In fig. 36 AO represents an upright axis or spindle; B a weight called a *bob*, suspended by a rod OB from a horizontal axis at O, carried by the vertical axis. When the spindle is at rest the bob hangs close to it; when the spindle rotates, the bob, being made to revolve round it, diverges until the resultant of the centrifugal force and the weight of the bob is a force acting at O in the direction OB, and then it revolves steadily in a circle. This combination is called a *revolving*, *centrifugal*, or *conical pendulum.* Revolving pendulums are usually constructed with *pairs* of rods and bobs, as OB, O*b*, hung at opposite sides of the spindle, that the centrifugal forces exerted at the point O may balance each other.

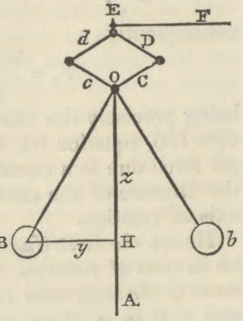


Fig. 36.

In finding the position in which the bob will revolve with a given angular velocity a, for most practical purposes connected with machinery the mass of the rod may be considered as insensible compared with that of the bob. Let the bob be a sphere, and from the centre of that sphere draw $BH = y$ perpendicular to OA. Let $OH = z$; let W be the weight of the bob, F its centrifugal force. Then the condition of its steady revolution is $W : F :: z : y$; that is to say, $\frac{y}{z} = \frac{F}{W} = \frac{ya^2}{g}$; consequently,

$$z = \frac{g}{a^2} \quad \ldots \ldots (86.)$$

Or, if $n = \frac{a}{2\pi} = \frac{a}{6{\cdot}2832}$ be the number of turns or fractions of a turn in a second,

$$z = \frac{g}{4\pi^2 n^2} = \frac{0{\cdot}8165 \text{ foot}}{n^2} = \frac{9{\cdot}79771 \text{ inches}}{n^2} \quad (87.)$$

z is called the *altitude of the pendulum.*

If the rod of a revolving pendulum be jointed, as in fig. 37, not to a point in the vertical axis, but to the end of a projecting arm C, the position in which the bob will revolve will be the same as if the rod were jointed to the point O, where its prolongation cuts the vertical axis.

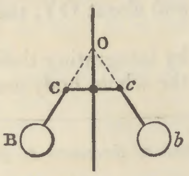


Fig. 37.

A revolving pendulum is an essential part of most of the contrivances called *governors,* for regulating the speed of prime movers.

The earlier kinds of governors act on the prime mover by the variations of their altitude. Thus, in Watt's steam-engine governor the rods, through a combination of levers and linkwork C*c*, D*d* (fig. 36), act on a lever EF, which acts upon the throttle-valve for the admission of steam so as to enlarge its opening when the speed becomes too small, and contract it when the speed becomes too great.

In a more recent kind of governors invented by the Messrs Siemens, which may be called *differential governors,* the regulation of the prime mover is effected by means of the difference between the velocity of a wheel driven by it and that of a wheel regulated by a revolving pendulum. Fig. 38 illustrates this class of governors: A is a vertical dead-centre or fixed shaft, about which the after-mentioned pieces turn; C is a pulley driven by the prime mover, and fixed to a bevel-wheel, which is seen below it; E is a bevel-wheel similar to the first, and having the same apex. To this wheel are hung the bobs B, of which there are usually four, although two only are shown. Those bobs form sectors of a ring, and are surrounded by a cylindrical casing F. When the bobs revolve with their proper velocity, they are adjusted so as nearly to touch this casing; should they exceed that velocity, they fly outwards and touch the casing, and are retarded by the friction. For practical purposes their velocity of rotation about the vertical axis may be considered constant. G, G are horizontal arms projecting from a socket, which is capable of rotation about A, and carrying vertical bevel wheels which rest on E and support C, and transmit motion from C to E. There are usually four of the arms G, G with their wheels, though two only are shown. H is one of those arms which projects, and has a rod attached to its extremity to act on the throttle-valve of a steam-engine, the sluice of a water-wheel, or the regulator of the prime mover, of what sort soever it may be.

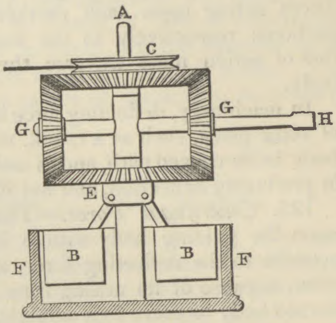


Fig. 38.

When C rotates with an angular velocity equal and contrary to that of E with its revolving pendulums, the arms G, G remain at rest; but should C deviate from that velocity, those arms rotate in one direction or the other, as the case may be, with an angular velocity equal to one-half of the difference between the angular velocity of C and that of E, and continue in motion until the regulator is adjusted so that the prime mover shall impart to C an angular velocity exactly equal to that of the revolving pendulums.

There are various modifications of the differential governor, but they all act on the same principle.

DIVISION III.—WORKING OF MACHINES OF VARYING VELOCITY.

130. *General Principles.*—In order that the velocity of every piece of a machine may be uniform, it is necessary that the forces acting on each piece should be always exactly balanced. Also, in order that the forces acting on each piece of a machine may be always exactly balanced, it is necessary that the velocity of that piece should be uniform.

An excess of the effort exerted on any piece, above that which is necessary to balance the resistance, is accompanied with acceleration; a deficiency of the effort, with retardation.

When a machine is being started from a state of rest, and brought by degrees up to its proper speed, the effort must be in excess; when it is being retarded for the purpose of stopping it, the resistance must be in excess.

An excess of effort above resistance involves an excess of energy exerted above work performed; that excess of energy is employed in producing acceleration.

An excess of resistance above effort involves an excess of work performed above energy expended; that excess of work is performed by means of the retardation of the machinery.

When a machine undergoes alternate acceleration and retardation, so that at certain instants of time, occurring at the end of intervals called *periods* or *cycles*, it returns to its original speed, then in each of those periods or cycles the alternate excesses of energy and of work neutralize each other; and at the end of each cycle the principle of the equality of energy and work stated in sect. 105, with all its consequences, is verified exactly as in the case of machines of uniform speed.

At intermediate instants, however, other principles have also to be taken into account, which are deduced from the second law of motion, sect. 95, as applied by the aid of the principles of sect. 96, to *direct deviation*, or acceleration and retardation.

131. *Energy of Acceleration and Work of Retardation for a Shifting Body.*—Let w be the weight of a body which has a motion of translation in any path, and in the course of the interval of time Δt let its velocity be increased at an uniform rate of acceleration from v_1 to v_2. The rate of acceleration will be

$$\frac{dv}{dt}=\text{constant}=\frac{v_2-v_1}{\Delta t};$$

and, according to sect. 96, equation 60, to produce this acceleration a uniform effort will be required, expressed by

$$\mathrm{P}=\frac{w\cdot(v_2-v_1)}{g\Delta t}. \quad . \quad . \quad . \quad (88.)$$

(The product $\frac{wv}{g}$ of the mass of a body by its velocity is called its *momentum;* so that the effort required is found by dividing the increase of momentum by the time in which it is produced.)

To find the *energy* which has to be exerted to produce the acceleration from v_1 to v_2, it is to be observed that the *distance* through which the effort P acts during the acceleration is

$$\Delta s=\frac{v+v}{2}\Delta t;$$

consequently, the *energy of acceleration* is

$$\mathrm{P}\Delta s=\frac{w(v_2-v_1)\,(v_2+v_1)}{2g}=\frac{w(v_2{}^2-v_1{}^2)}{2g}, \quad . \quad (89.)$$

being proportional to the increase in the square of the velocity, and *independent of the time.*

In order to produce a *retardation* from the greater velocity v to the less velocity v_1, it is necessary to apply to the body a *resistance*, connected with the retardation and the time by an equation identical in every respect with equation 88, except by the substitution of a resistance for an effort; and in overcoming that resistance the body *performs work* to an amount determined by equation 89, putting Rds for Pds.

132. *Energy Stored and Restored by Deviations of Velocity.*—Thus a body alternately accelerated and retarded, so as to be brought back to its original speed, performs work during its retardation exactly equal in amount to the energy exerted upon it during its acceleration; so that that energy may be considered as *stored* during the acceleration, and *restored* during the retardation, in a manner analogous to the operation of a reciprocating force (sect. 123).

Let there be given the mean velocity $\mathrm{V}=\frac{v_2+v_1}{2}$ of a body whose weight is w, and let it be required to determine the fluctuation of velocity v_2-v_1, and the extreme velocities v_1, v_2, which that body must have, in order alternately to store and restore an amount of energy E. By equation 30 we have

$$\mathrm{E}=\frac{w(v_2{}^2-v_1{}^2)}{2g},$$

which, being divided by $\mathrm{V}=\frac{v_1+v_2)}{2}$, gives

$$\frac{\mathrm{E}}{\mathrm{V}}=\frac{w(v_2-v_1)}{g};$$

and consequently

$$v_2-v_1=\frac{g\mathrm{E}}{\mathrm{V}w} \quad . \quad . \quad . \quad . \quad . \quad (90.)$$

The ratio of this fluctuation to the mean velocity, sometimes called the *unsteadiness* of the motion of the body, is

$$\frac{v_2-v_1}{\mathrm{V}}=\frac{g\mathrm{E}}{\mathrm{V}^2w}. \quad . \quad . \quad . \quad . \quad . \quad (91.)$$

133. *Actual Energy of a Shifting Body.*—The energy which must be exerted on a body of the weight w, to accelerate it from a state of rest up to a given velocity of translation v, and the equal amount of work which that body is capable of performing by overcoming resistance while being retarded from the same velocity of translation v to a state of rest, is

$$\frac{wv^2}{2g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (92.)$$

This is called the *actual energy* of the motion of the body, and is one-half of the quantity which is called *vis-viva* in some treatises on mechanics.

The energy stored or restored, as the case may be, by the deviations of velocity of a body, or a system of bodies, is the amount by which the actual energy is increased or diminished, as the case may be.

134. *Principle of the Conservation of Energy in Machines.*—The following principle, expressing the general law of the action of machines with a velocity uniform or varying, includes the law of the equality of energy and work stated in sect. 105 for machines of uniform speed.

In any given interval during the working of a machine, the energy exerted added to the energy restored is equal to the energy stored added to the work performed.

135. *Actual Energy of Circular Translation—Moment of Inertia.*—Let a body of the weight w undergo translation in a circular path of the radius ρ, with the angular velocity of deflection α, so that the common linear velocity of all its particles is $v=\alpha\rho$. Then the actual energy of that body is

$$\frac{wv^2}{2g}=\frac{w\alpha^2\rho^2}{2g}. \quad . \quad . \quad . \quad . \quad . \quad (93.)$$

By comparing this with equation 82, sect. 124, it appears that the actual energy of a revolving body is equal to the potential energy $\frac{\mathrm{F}\rho}{2}$ due to the action of the deflecting force along one-half of the radius of curvature of the path of the body.

The product $\frac{w\rho^2}{g}$ by which the half-square of the angular-velocity is multiplied, is called the *moment of inertia* of the revolving body.

136. *Actual Energy and Moment of Inertia of Rotation —Radius of Gyration.*—Let a body of any figure BB (see fig. 35, sect. 126) rotate about the axis of rotation O, perpendicular to the plane XOY; let w be the entire weight of the body; let α be its angular velocity of rotation, being also the angular velocity of deflection of each of its particles in its revolution round the axis. Conceive the body to be divided into an indefinite number of indefinitely small particles; denote the weight of one of them by dW; and let its perpendicular distance from the axis be ρ. The actual energy of that particle, according to sect. 135, is

$$\frac{\alpha^2\rho^2\cdot dW}{2g};$$

and the actual energy of the whole body, being the sum or integral of the actual energies of its particles, is

$$\frac{\alpha^2}{2g}\int\rho^2\cdot dW. \quad . \quad . \quad . \quad (94.)$$

The integral in this expression, by which the half-square of the angular velocity is multiplied, viz.,—

$$\frac{1}{g}\int\rho^2\cdot dW = I, \quad . \quad . \quad . \quad (95.)$$

is the *moment of inertia* of the whole body relatively to the given axis O, being the sum of the moments of inertia of all its particles. The actual energy of the body may be thus expressed:

$$\frac{I\alpha^2}{2} \quad . \quad . \quad . \quad . \quad . \quad (96.)$$

If the moment of inertia be divided by the mass $\frac{W}{g}$ of the body, the result is

$$R^2 = \frac{gI}{W}, \quad . \quad . \quad . \quad . \quad (97.)$$

the square of a length called the *radius of gyration;* being the distance from the axis O at which, if the whole mass of the body were collected at one or more points, or in a ring, or hollow cylinder, the moment of inertia would be the same with that of the actual body.

If the given axis O do not already traverse the centre of gravity of the body, conceive an axis parallel to it to be drawn through that centre of gravity, and designated by the symbol G. Let $\rho_1 = \overline{OG}$ be the perpendicular distance between those axis. Let R_0 be the radius of gyration, and $I_0 = \frac{R_0^2W}{g}$, the moment of inertia of the body about the axis G. Then, from geometrical properties of the centre of gravity, the proof of which belongs to the subject of statics, it is known that

$$R^2 = R_0^2 + \rho_1^2; \quad . \quad . \quad . \quad . \quad (98.)$$

from which it follows that

$$I = I_0 \times \frac{\rho_1^2W}{g}; \quad . \quad . \quad . \quad . \quad (99.)$$

that is to say, *the moment of inertia of a body about any axis* O, *not traversing its centre of gravity, is equal to the moment of inertia of the whole body about an axis* G, *traversing the centre of gravity parallel to* O, *added to the moment of inertia due to a circular translation of the whole body with the radius* $\overline{OG}$.[1]

From equation 99 it follows obviously, that the moment of inertia of a body about an axis traversing its centre of gravity in a given direction, is less than about any other axis parallel to that direction.

The respective moments of inertia of a body about its permanent axes of rotation (sect. 128), are called its *principal moments of inertia.*

137. *Examples of Radii of Gyration.*—The following are some examples, useful in practice, of the radii of gyration of homogeneous solids about permanent axes:—

I. A sphere of the radius r rotating about a diameter, ... $R_0^2 = \frac{2r^2}{5}$

II. A spheroid of revolution rotating about its polar axis, its equatorial radius being r, $R_0^{2'} = \frac{2r^2}{5}$

III. An ellipsoid whose semi-axes are a, b, c, rotating about the axis $2a$, ... $R_0^2 = \frac{b^2+c^2}{5}$

IV. A cylindrical disc of the radius r, rotating about its axis of figure, ... $R_0^2 = \frac{r^2}{2}$

V. A cylindrical ring, or hollow cylinder, rotating about its axis of figure, the external and internal radii being r, r^1, ... $R_0^2 = \frac{r^2+r^{12}}{2}$
(This is applicable to many cases of rims of fly-wheels.)

VI. A rectangular parallelopiped whose dimensions are $2a$, $2b$, $2c$, rotating about the axis whose length is $2a$, ... $R_0^2 = \frac{b^2+c^2}{3}$

VII. A slender rod of uniform section and length $2l$, rotating about an axis crossing it at right angles in the middle of its length, $R_0^2 = \frac{l^2}{3}$
(This case is also applicable to any system of rods of equal length l, radiating from a common axis, like the spokes of a fly-wheel.)

VIII. A system of bodies of respective weights w, w', w'', &c., rotating about a common axis, and having the respective radii of gyration ρ, ρ', ρ'', &c., ... $R_0^2 = \frac{\Sigma\cdot w\rho}{\Sigma\cdot w}$

138. *Fly-Wheels.*—A fly-wheel is a rotating piece in a machine, generally shaped liked a wheel (that is to say, consisting of a rim with spokes), and suited to store and restore energy by the periodical variations in its angular velocity.

The principles according to which variations of angular velocity store and restore energy are the same with those of sect. 132, only substituting *moment of inertia* for *mass*, and *angular* for *linear* velocity.

Let W be the weight of a fly-wheel, R its radius of gyration, α_2 its maximum, α_1 its minimum, and $A = \frac{\alpha_2+\alpha_1}{2}$ its mean angular velocity. Let

$$\frac{1}{S} = \frac{\alpha_2 - \alpha_1}{A}$$

denote the *unsteadiness* of the motion of the fly-wheel; the denominator S of this fraction is called the *steadiness.* Let e denote the quantity by which the energy exerted in each cycle of the working of the machine alternately exceeds and falls short of the work performed, and which has consequently to be alternately stored by acceleration, and restored by retardation of the fly-wheel. The value of this *periodical excess* is—

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[1] This is a particular case of a more general proposition, that *the whole actual energy of any system of masses is equal to the actual energy due to a motion of the whole of those masses with the velocity of their common centre of gravity, added to the sum of the actual energies due to the several motions of the several masses relatively to that common centre of gravity.*

$$e=\frac{R^2W(a_2{}^2-a_1{}^2)}{2g}; \quad . \quad . \quad . \quad (100.)$$

from which, dividing both sides by A^2, we obtain the following equations:—

$$\left.\begin{array}{l}\frac{e}{}=\frac{R^2W}{gS};\\ \frac{R^2WA^2}{2g}=\frac{Se}{2}.\end{array}\right\} \quad . \quad . \quad . \quad (101.)$$

The latter of these equations may be thus expressed in words:—*The actual energy due to the rotation of the fly, with its mean angular velocity, is equal to one-half of the periodical excess of energy multiplied by the steadiness.*

In ordinary machinery, S = about 32; in machinery for fine purposes S = from 50 to 60.

The periodical excess e may arise either from variations in the effort exerted by the prime mover, or from variations in the resistance of the work, or from both these causes combined. When but one fly-wheel is used, it should be placed in as direct connection as possible with that part of the mechanism where the greatest amount of the periodical excess originates; but when it originates at two or more points, it is best to have a fly-wheel in connection with each of those points. For example, in a machine-work, the steam-engine, which is the prime mover of the various tools, has a fly-wheel on the crank-shaft to store and restore the periodical excess of energy arising from the variations in the effort exerted by the connecting-rod upon the crank; and each of the slotting machines, punching machines, rivetting-machines, and other tools, has a fly-wheel of its own to store and restore energy, so as to enable the very different resistances opposed to those tools at different times to be overcome without too great unsteadiness of motion.

According to the computation of General Morin, the periodical excess e in steam-engines with single cranks is from $\frac{1}{10}$th to nearly $\frac{1}{4}$th of the energy exerted during one revolution of the crank. For a pair of steam-engines driving one shaft, with a pair of cranks at right angles to each other, the value of e is one-fourth of its value for a single cranked engine of the same kind, and of the same power with the two combined.

The ordinary radius of gyration of a steam-engine fly-wheel is from three to five times the length of the crank-arm. (For further particulars on this subject, see STEAM-ENGINE.)

For tools performing useful work at intervals, and having only their own friction to overcome during the intermediate intervals, e should be assumed equal to the whole work performed at each separate operation.

139. *Brakes.*—A brake is an apparatus for stopping or diminishing the velocity of a machine by friction, such as the friction-strap already referred to in sect. 118. To find the distance s through which a brake, exerting the friction F, must rub in order to stop a machine having the total actual energy E at the moment when the brake begins to act, reduce, by the principles of sect. 111, the various efforts and other resistances of the machine which act at the same time with the friction of the brake to the rubbing surface of the brake, and let R be their resultant,—*positive* if resistance, *negative* if effort preponderates. Then

$$s=\frac{E}{F+R} \quad . \quad . \quad . \quad . \quad (102.)$$

140. *Energy distributed between two Bodies—Projection and Propulsion.*—Hitherto the effort by which a machine is moved has been treated as a force exerted between a moveable body and a fixed body, so that the whole energy exerted by it is employed upon the moveable body, and none upon the fixed body. This conception is sensibly realized in practice when one of the two bodies between which the effort acts is either so heavy as compared with the other, or has so great a resistance opposed to its motion, that it may, without sensible error, be treated as fixed. But there are cases in which the motions of both bodies are appreciable, and must be taken into account; such as the projection of projectiles, where the velocity of the *recoil* or backward motion of the gun bears an appreciable proportion to the forward motion of the projectile; and such as the propulsion of vessels, where the velocity of the water thrown backward by the paddle, screw, or other propeller, bears a very considerable proportion to the velocity of the water moved forwards and sideways by the ship. In cases of this kind the energy exerted by the effort is *distributed* between the two bodies between which the effort is exerted, in shares proportional to the velocities of the two bodies during the action of the effort; and those velocities are to each other, directly as the portions of the effort unbalanced by resistance on the respective bodies, and inversely as the weights of the bodies.

To express this symbolically, let W_1, W_2 be the weights of the bodies; P the effort exerted between them; S the distance through which it acts; R_1, R_2 the resistances opposed to the effort overcome by W_1, W_2 respectively; E_1, E_2 the shares of the whole energy E exerted upon W_1, W_2 respectively. Then

$$\left.\begin{array}{ccccc} E & : & E_1 & : & E_2 \\ ::\frac{W_2(P-R_1)+W_1(P-R_2)}{W_1W_2} & : & \frac{P-R_1}{W_1} & : & \frac{P-R_2}{W_2}\end{array}\right\} (103.)$$

If $R_1=R_2$, which is the case when the resistance, as well as the effort, arises from the mutual actions of the two bodies, the above becomes,

$$\left.\begin{array}{ccccc} E & : & E_1 & : & E_2 \\ ::W_1+W_2 & : & W_2 & : & W_1\end{array}\right\}; \quad . \quad . \quad (104.)$$

that is to say, the energy is exerted on the bodies in shares inversely proportional to their weights; and they receive accelerations inversely proportional to their weights, according to the principle of dynamics, already quoted in a note to sect. 127, that the mutual actions of a system of bodies do not affect the motion of their common centre of gravity.

For example, if the weight of a gun be 160 times that of its ball, $\frac{160}{161}$ of the energy exerted by the powder in exploding will be employed in propelling the ball, and $\frac{1}{161}$ in producing the recoil of the gun; provided the gun, up to the instant of the ball's quitting the muzzle, meets with no resistance to its recoil except the friction of the ball.

141. *Centre of Percussion.*—In order that a rigid solid body may have a given deviation imparted to it, it is sufficient that the *resultant* of the unbalanced force or forces applied to it should be identical in magnitude, direction, and position, with the *resultant* of the forces, which, if applied separately to the several particles of the body, would give each of them the deviation which it is required to have as forming a part of the body.[1] The nearest point in the line of action of this resultant to the centre of gravity of the body is called the *centre of percussion* of the body for the given kind of deviation. It indicates the position and direction in which a *single* force must act in order to produce deviation in the required manner. (Details respecting the centre of percussion will be found in the article DYNAMICS.)

It is obviously desirable that the deviations or changes of motion of oscillating pieces in machinery should, as far as possible, be effected by forces applied at their centres of percussion.

If the deviation be a *translation*,—that is an equal change of motion of all the particles of the body,—the centre of percussion is obviously the centre of gravity itself; and, as already stated (sect. 96, equation 60), if dv be the deviation of velocity to be produced in the interval dt, and W the weight of the body,—

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[1] This is a particular case of the principle of Dynamics, known as "D'Alembert's principle."

$$P=\frac{W}{g}\cdot\frac{dv}{dt} \quad . \quad . \quad . \quad . \quad (105.)$$

is the unbalanced effort required.

If the deviation be a rotation about an axis traversing the centre of gravity, there is no centre of percussion; for such a deviation can only be produced by a *couple* of forces, and not by any single force. Let da be the deviation of angular velocity to be produced in the interval dt; I the moment of inertia of the body; then $\frac{1}{2}Id(a^2)=Iada$ is the variation of the body's actual energy. Let M be the moment of the unbalanced couple required to produce the deviation; then, by equation 70, sect. 110, the energy exerted by this couple in the interval dt is $Madt$, which, being equated to the variation of energy, gives

$$M=I\frac{da}{dt}=\frac{R_0^2W}{g}\cdot\frac{da}{dt} \quad . \quad . \quad . \quad . \quad (106.)$$

Now, let the required deviation be a rotation of the body BB about an axis O, not traversing the centre of gravity G, da being, as before, the deviation of angular velocity to be produced in the interval dt. According to the principle of sect. 44, a rotation with the angular velocity a about an axis O may be considered as compounded of a rotation with the same angular velocity about an axis drawn through G parallel to O, and a translation with the velocity $a\cdot\overline{OG}$; $\overline{OG}$ being the perpendicular distance between the two axes. Hence the required deviation may be regarded as compounded of a deviation of translation $dv=OG\cdot da$, to produce which there would be required, according to equation 105, a force applied at G perpendicular to the plane OG—

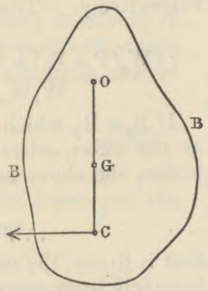


Fig. 39.

$$P=\frac{W}{g}\cdot\overline{OG}\cdot\frac{da}{dt}, \quad . \quad . \quad . \quad (107.)$$

and a deviation da of rotation about an axis drawn through G parallel to O, to produce which there would be required a couple of the moment M given by equation 106. According to the principles of statics, the resultant of the force P applied at G perpendicular to the plane OG, and of the couple M, is a force equal and parallel to P, but applied at a distance $\overline{GC}$ from G, in the prolongation of the perpendicular $\overline{OG}$, whose value is

$$\overline{GC}=\frac{M}{P}=\frac{R_0^2}{\overline{OG}}\cdot \quad . \quad . \quad . \quad (108.)$$

Thus is determined the position of the centre of percussion C, corresponding to the axis of rotation O. It is obvious from this equation that, for an axis of rotation parallel to O traversing C, the centre of percussion is at the point where the perpendicular $\overline{OG}$ meets O.

142. *Impact.*—Impact or collision is a pressure of short duration exerted between two bodies. (For the detailed investigation of its laws the reader is referred to DYNAMICS.)

The effects of impact are sometimes an alteration of the distribution of actual energy between the two bodies, and always a loss of a portion of that energy, depending on the imperfection of the elasticity of the bodies, in permanently altering their figures, and producing heat. The determination of the distribution of the actual energy after collision, and of the loss of energy, is effected by means of the following principles:—

I. The motion of the common centre of gravity of the two bodies is unchanged by the collision.

II. The loss of energy consists of a certain proportion of that part of the actual energy of the bodies which is due to their motion relatively to their common centre of gravity.

Unless there is some special reason for using impact in machines, it ought to be avoided, on account not only of the waste of energy which it causes, but of the damage which it occasions to the frame and mechanism.

CHAPTER III.—PURPOSES AND EFFECTS OF MACHINES.

143. *Observing Machines and Working Machines.*—The present chapter must necessarily be limited to some very general observations on the principal classes into which machines may be divided, with reference to their purposes and effects, leaving the reader to find, under special heads in this Encyclopædia, the detailed descriptions of particular examples.

Machines may be divided, in the first instance, into two great divisions, viz.:—

I. *Observing machines*, in which either the modification of motion alone, or the balancing of forces alone, is the object in view,—the performance of work being either null or incidental, and being limited to that which arises from the resistance of the machine.

II. *Working machines*, in which the performance of work is the main object.

144. *Classification of Observing Machines.*—Observing machines might very properly have been classed as *instruments*, being designed to aid the human senses and memory in obtaining and recording information. They may be divided, in the first instance, into four classes, according as the subject of observation by their aid is number, measure, or weight, into—

A: Counting machines.
B: Measuring machines.
C: Copying and drawing machines.
D: Weighing machines.

And to these may be added a fifth class, in which the functions of the first four are more or less combined, viz.,—

E: Recording machines.

145. *Counting Machines.*—The most important as well as the most common of counting machines are *time-keepers*, which count and indicate the numbers of oscillations of bodies which oscillate isochronously (viz., pendulums for clocks, balance-wheels for watches and marine chronometers) so as to measure time. In constructing such machines, the objects to be aimed at are the exact isochronism of the pendulum or balance, and the equable action of the motive power, so that it shall overcome the friction of the mechanism without affecting the rate. (See CHRONOMETER; CLOCK AND WATCH WORK; PENDULUM.)

Other counting machines count the oscillations of the beam of a steam-engine, the revolutions of the cylinder of a gas-meter, or of the wheel of a water-meter.

Others perform additions, subtractions, and multiplications, and of these the most elaborate kind (of which there are but two in existence,—the machine of Mr Babbage and that of Messrs Scheutz) compute tables of functions by the addition of differences.

146. *Measuring Machines.*—Measuring machines are pieces of mechanism, by means of which the motion of

some body of the nature of an index through some geometrical magnitude, such as a distance or an angle, is connected with some other motion, either equal or greater or smaller in some given ratio, and capable of being more readily compared with some standard of measure.

To this class belong all those astronomical and surveying instruments in which the motion of a line of sight (generally the line of collimation of a telescope) through a given angle is connected with the motion of an index or vernier round a corresponding arc of a graduated circle; also those micrometers in which the advance of the end of a screw of fine pitch is measured by observing the simultaneous arc of rotation of a graduated circle which is attached to it.

Such micrometers have attained increased importance by the discovery of Mr Whitworth,—that the mechanical magnifying of small distances by a train of screws affords a more accurate means of measurement than optical magnifying by the microscope,—and by the perfection to which that engineer has brought that art of accurate workmanship which is necessary in order to render mechanical magnifying possible.

Amongst measuring machines are included the *platometers* or *planimeters* of Mr Sang, General Morin, and Mr Clerk Maxwell, which measure areas by means of mechanism. The amount of resistance in a measuring-machine should be perfectly uniform, and sufficiently great to prevent accidental forces from disturbing the machine, without being so great as to render it inconveniently stiff. To combine these objects requires great accuracy of workmanship, together with strength and rigidity in the structure of the frame and mechanism.

147. (C.) *Copying and Drawing Machines.*—In copying-machines for enlarging or reducing drawings there is usually a combination of levers and linkwork connecting a tracing-point, which is moved over the lines of the original figure with a drawing-point, which draws the copy in such a manner that the velocity-ratio of their motions is a given constant quantity, and that the directions of their motions make a constant angle.

Mechanism, depending for its principles on the theory of the composition of rotations, is used to draw ellipses, epicycloids, epitrochoids, and other curves.

148. (D.) *Weighing Machines.*—In weighing machines the motion of the mechanism is used only for the purpose that its cessation, or its becoming an oscillation about a certain position, may indicate the equilibrium of the forces applied to the machine. Those forces may either be weights, which are to be compared with each other, or forces of other kinds, to be compared directly or indirectly with weights.

The machine for comparing weights, which is capable of the most minute accuracy, is also the simplest, being the *balance*, in which the equality of two weights is ascertained by their balancing each other at the ends of a lever of equal arms. In the *steelyard*, consisting either of one lever or of a train of levers, the unknown weight has an unchangeable point of application, and is compared with a known weight by shifting the latter along the lever to which it is applied until the machine is balanced; the ratio of the weights is then the reciprocal of the velocity-ratio of their points of application. The steelyard is more convenient for weighing very heavy loads than the balance, but not capable of such minute accuracy.

It is essential to accuracy in balances and steelyards that the friction should be less than the smallest admissible amount of error. To diminish the friction as much as possible, the axes of motion are all *knife-edges*, as they are termed, of steel or hardened iron, resting on hard surfaces of hardened iron or steel for ordinary purposes, and of some hard mineral, such as agate, for scientific purposes.

The weight of a column of fluid is determined by balancing it against a column of fluid whose weight is known, as in the barometer, where the weight of a column of the atmosphere is balanced against that of a column of mercury.

Weights are compared with each other indirectly, and other forces compared with weights, by means of their effects in bending a spring,—a convenient method, but not susceptible of minute accuracy.

The elastic pressure exerted by a fluid may be compared with weight, either by balancing the pressure against the weight of a column of liquid, or by maintaining a piston in equilibrio against that pressure, by means of a weight pressing it directly, or of a weight acting through a steelyard, or of the elasticity of a spring which has been compared with weights.

149. (E.) *Recording Machines.* — Recording-machines may be divided into two classes: *self-registering instruments*, which, by the aid of clockwork, record measurements either of space or of force, together with the instants of time at which these measurements were made; and *dynamometers*, already mentioned in chap. II. of this article, which register measurements of force, together with the space through which it has acted, thus recording energy or work.

150. *Working Machines Classed.*—The object or purpose of working-machines is to perform useful work; and their classification relatively to their objects and purposes is founded on the kind of useful work which they perform. In this point of view they may be classed as follows:—

A: Machines for lifting or lowering solid weights.
B: Machines for the horizontal transport of weights, either combined or not with lifting or lowering.
C: Machines for projecting solids.
D: Machines for lifting fluids.
E: Machines for propelling or projecting fluids.
F: Machines for dividing bodies.
G: Machines for shaping bodies by removing portions of them.
H: Machines for shaping bodies by pressure.
I: Machines for uniting bodies into fabrics.
J: Machines for printing.
K: Machines for producing sound.
L: Miscellaneous machines.

The author of this article does not pretend to assert that the above classification (taken to a considerable extent from the writings of Young and of Mr Babbage) exhausts all kinds of machines: he brings it forward merely as an attempt to introduce method to a certain extent into a subject which would otherwise be exceedingly confused.

151. (A.) *Machines for Lifting and Lowering Solids.*—The most common machines of this class are *capstans*, *cranes*, and *windlasses*. They are usually worked by manual labour, but sometimes by hydraulic engines, or by steam-engines. The useful resistance, when a load is lifted, being the weight of that load, is in general greater than the effort exerted by the prime mover, so that the mechanism has to be adapted to giving the working-piece a less velocity than the piece to which the effort is applied. In lowering solid loads the weight of the load acts as the effort, and the energy exerted by it is expended in overcoming the friction of a brake in order that the speed of descent may not be excessive.

152. (B.) *Transporting Machines.*—The mechanism of transporting machines consists of two parts: that by which the resistance is diminished, as the wheels and axles of vehicles; and that by which the resistance is overcome and the load propelled, comprising all kinds of locomotive and propelling machinery. Transporting machines are treated of in the articles relating specially to the lines of conveyance to which they are applied; such as CANALS, RAILROADS, ROADS, and STEAM NAVIGATION.

153. (C.) *Machines for Projecting Solids.*—This class comprehends all kinds of artillery.

154. (D.) *Machines for Lifting Fluids.*—(See Hydrodynamics and Pneumatics.)

155. (E.) *Machines for Propelling or Projecting Fluids.*—(See the same articles.)

156. (F.) *Machines for Dividing Bodies.*—This class comprehends all machines for separating solid masses into parts, whether by digging, cutting, sawing, grinding, tearing, crushing, pounding, pressing out fluids, or otherwise; and whether applied to earth, stones, metals, timber, fruit, grain, fibres, or other materials.

157. (G.) *Machines for Shaping Bodies by removing portions of them.*—This class of machines to a certain extent resembles the preceding. It includes machines for cutting, grinding, and polishing blocks of stone into required figures; shaping pieces of wood, metal, or other material, whether by *turning*, to produce spherical, cylindrical, and other curved surfaces,—by *boring*, *punching*, *slotting*, or *gouging*, to produce cylindrical, rectangular, or other orifices and grooves,—by *screw-cutting*, by *planing*, by *grinding* and *polishing*, to produce curved or plane surfaces. The most difficult and important of all these operations is to produce a surface truly plane; and the perfecting of this operation by Mr Whitworth is the most important step recently made in *Constructive Mechanics*, or the art of making machines and instruments. Next in point of difficulty may be placed the art of forming the concave reflecting surfaces of great specula for telescopes, such as those of the Herschels, of Mr Lassell, and of Lord Rosse.

158. (H.) *Machines for Shaping Bodies by Pressure* comprehend amongst others, *rolling-mills* for iron, *steam-hammers*, *wire-drawing* machines, *pinmaking* and *nail-making* machines, *coining* and other *stamping* machinery, *brickmaking* machines, *presses* for packing and compressing, &c., &c.

159. (I.) *Machines for Uniting Bodies into Fabrics* comprise *spinning* machinery, whether applied to ropes, yarn, or thread, *weaving* machinery of all kinds, *papermaking* machinery, *felting* machinery, and *sewing* machinery.

160. (J.) *Machines for printing* are used to apply either colouring matters or matters for discharging colour to paper, cloth, and other materials.

161. (K.) *Machines for Producing Sound.*—(See Acoustics, and Music.)

162. (L.) *Miscellaneous Machines.*—There are numerous machines which perform processes, especially in the preparation of textile fabrics for the market, which it would be almost impossible to class. Examples of such machines will be found by referring to the articles relating to the various branches of manufacture.

CHAPTER IV.—APPLIED ENERGETICS, OR THEORY OF PRIME MOVERS.

163. *Prime Movers in general: their Efficiency.*—Prime movers, or receivers of power, are those pieces or combinations of pieces of mechanism, which receive motion and force directly from some natural source of energy. The point where the mechanism belonging to the prime mover ends, and that belonging to the train for modifying the force and motion begins, is somewhat arbitrary; in general, however, the mechanism belonging to the prime mover may be held to include all pieces which regulate or assist in regulating the transmission of energy from the source of energy. Thus in the ordinary rotative steam-engine, the crank-shaft belongs to the prime mover, because it carries the eccentric which moves the valves, and the fly-wheel which stores and restores the periodical excess of energy of the engine, and drives the governor (when there is one) which regulates the admission of steam.

The *useful work* of the prime mover is the energy exerted by it upon that piece which it directly drives; and the ratio which this bears to the energy exerted by the source of energy is the *efficiency* of the prime mover.

It is often convenient to divide the prime mover into sections, and resolve its efficiency into factors, each factor being the efficiency of one of those sections. Thus the efficiency of a steam-engine may be resolved into the following factors:—

Efficiency of the furnace and boiler; being the proportion of the total heat of combustion of the fuel which takes effect in heating and evaporating the water.

Efficiency of the steam in driving the piston; being the proportion of the energy exerted by the steam on the piston (called the *indicated* energy or power, as being measured by an indicator), to the mechanical equivalent of the heat received by the water.

Efficiency of the mechanism from the piston to the crank-shaft inclusive; being the proportion of the effective energy transmitted by the crank-shaft to the indicated energy.

The product of those three factors is the efficiency of the engine as a whole.

In all prime movers the loss of energy may be distinguished into two parts; one being the unavoidable effect of the circumstances under which the machine necessarily works in the case under consideration; the other the effect of causes which are, or may be, capable of indefinite diminution by practical improvements. Those two parts may be distinguished as *necessary loss* and *waste.*

The efficiency which a prime mover would have under given circumstances if the *waste* of energy were altogether prevented, and the loss reduced to necessary loss alone, is called the *maximum* or the *theoretical* efficiency under the given circumstances.

For some prime movers there is a combination of circumstances which makes the theoretical efficiency greater than any other combination does. The theoretical efficiency under those circumstances is the *absolute maximum efficiency.*

The *duty* of a prime mover is its useful work in some given unit of time; as a second, a minute, an hour, a day. In some cases, such as that of the work of animals, the duty can be ascertained, while the efficiency can only be inferred indirectly or conjecturally from the want of precise data as to the whole energy expended.

164. *Sources of Energy Classed.*—The sources of energy used in practice may be classed as follows:—

A: Strength of men and animals.
B: Weight of liquids.
C: Motion of fluids.
D: Heat.
E: Electricity and magnetism.

165. (A.) *Strength of Men and Animals.*—The *mechanical daily duty* of a man or of a beast is the product of three quantities: the effort, the velocity, and the number of units of time per day during which work is continued. It is well known that for each individual man or animal there is a certain set of values of those three quantities which make their product the daily duty a maximum, and that any departures from those values diminishes the daily duty. Attempts have been made to represent by a formula the law of this diminution; they have met with imperfect success. That which agrees on the whole best with the facts is the formula of Maschek, which is as follows:—Let P_1 be the effort, V_1 the velocity, and T_1 the time of working per day, which give the maximum daily duty; let P, V, T, be any other set of values of those quantities. Then

$$\frac{P}{P_1}+\frac{V}{V_1}+\frac{T}{T_1}=3 \quad . \quad . \quad . \quad . \quad (109.)$$

One consequence of this formula is, that the best time of working per day for men, and for all animals, is *one-third part of a day*, or eight hours; a conclusion in accordance with experience.

The best effort P_1, and the best velocity V_1, are much less certain; the difficulty of determining their true mean values for particular species being rendered very great by the differences not only between individuals, but between races or varieties of the same species. The following table of values is proposed by Maschek as approximately true:—

Animals.	Weighing.	P_1	V_1	$\frac{T_1}{3600}$	P_1V_1	$P_1V_1T_1$
		lb.	Feet per second.	Hours per day.	Ft.-lb. per sec.	Ft.-lb.
Man	150 lb.	30	2·5	8	75	2,160,000
Horse (draught)	600 lb.	120	4·0	8	480	13,824,000
Ox............	600 lb.	120	2·5	8	300	8,640,000
Ass............	360 lb.	72?	2·5	8	180	5,184,000?
Mule	500 lb.	100?	3·5	8	350	10,080,000?

Of the numbers in this table those for the draught horse are probably the most accurate. For the thorough-bred horse it is certain that the value of V_1 is much greater, and that of P_1 much less, than for the draught horse; the effect being probably that the *maximum* daily duty $P_1V_1T_1$ is nearly the same; but experimental data are wanting to determine these quantities with precision.

The following table, chiefly extracted from the works of Poncelet and Morin, with the addition of some results of experiments by Lieutenant David Rankine and by the author of this article, shows the daily duty of men and horses under certain specified circumstances:—

	P	V	$\frac{T''}{3600}$	PV	PVT
	lb.	Feet p. sec.	Hours p. day.	Foot-lb. per sec.	Foot-lb. per day.
MAN—					
1. Raising his own weight up stair or ladder	143	0·5	8	72·5	2,088,000
2. Do. do. do.	...	...	10	...	2,616,000
3. (Tread-wheel—See 1.)					
4. Hauling up weight with rope	40	0·75	6	30	648,000
5. Lifting weights by hand	44	0·55	6	24·2	522,720
6. Carrying weights up stairs ...	143	0·13	6	18·5	399,600
7. Shovelling up earth to a height of 5 ft. 3 in.	6	1·3	10	7·8	280,800
8. Wheeling earth in barrow up slope of 1 in 12; ½ horiz. veloc. 0·9 ft. per sec. (returning empty)...............	132	0·075	10	9·9	356,400
9. Pushing or pulling horizontally (capstan or oar)	26·5	2·0	8	53	1,526,400
10. Turning a crank or winch	12·5	5·0	?	62·5	
	18·0	2·5	8	45	1,296,000
	20·0	14·4	2 min.	288	
11. Working pump	13·2	2·5	10	33	1,188,000
12. Hammering	15	?	8?	?	480,000
HORSE—					
13. (Thorough-bred) cantering and trotting, drawing a light railway carriage....	min. 22½ mean 30½ max. 50	14⅔	4	447½	6,444,000
14. Horse (draught) drawing cart or boat, walking......	120	3·6	8	432	12,441,600

166. *Horizontal Transport.*—When men and animals carry burdens, or draw or propel loads in certain vehicles, it is difficult, and sometimes impossible, to determine the duty performed in foot-pounds of work, because of the uncertainty of the amount in pounds of the resistance overcome. In this case, for the purpose of comparing performances of the same kind with each other, a unit is employed called a *foot-pound of horizontal transport*; meaning the conveying of a load of 1 pound 1 foot horizontally. The following table, compiled from the sources referred to in sect. 165, gives some examples of the daily duty of men and horses in units of horizontal transport; L denoting the load in lb., V the velocity in feet per second, and T the number of seconds per day of working:—

	L	V	$\frac{T}{3600}$	LV	LVT
	lb.	Feet per second.	Hours per day.	lb. conveyed 1 foot.	lb. conveyed 1 foot.
MAN.—					
15. Walking unloaded, transport of own weight........................	140	5	10	700	25,200,000
Do. do.	140	6	10	840	30,240,000
16. Wheeling load L in 2-wheeled barrow, returning empty; V = ½ velocity........................	224	1⅔	10	373	13,428,000
17. Do. 1 wheeled barrow do.	135	1⅔	10	225	8,100,000
18. Travelling with burden	90	2½	7	225	5,670,000
19. Conveying burden, returning unloaded	140	1⅔	6	233	5,032,800
20. Carrying burden for 30 seconds only	252	...	...	...	......
	126	11·7	...	1474·2	......
	0	23·1	...	0	......
HORSE.—					
21. Walking with cart always loaded	1500	3·6	10	5400	194,400,000
22. Trotting do. do.	750	7·2	4½	5400	87,480,000
23. Walking with cart, going loaded, returning empty; V = ½ mean velocity	1500	2·0	10	3000	108,000,000
24. Carrying burden, walking	270	3·6	10	972	34,992,000
25. do. trotting	180	7·2	7	1296	32,659,200

167. (B.) *Weight of Liquids.*—(C.) *Motion of Fluids.*—In water-wheels and other hydraulic engines the weight and motion of a liquid usually act together as sources of energy.

To determine the necessary loss of energy and the theoretical efficiency, let Q denote the weight of liquid which acts on the wheel or other engine per second; H the vertical fall from the point where the liquid first begins to act directly or indirectly on the wheel or other engine, to the point where it ceases to act; V_1 the velocity of the liquid when it begins to act; and V_2 the least velocity, when it ceases to act, which will properly discharge the liquid, and prevent its accumulating so as to impede the wheel or engine. Then the *power* or energy exerted per second is—

$$\left.\begin{array}{l} Q\left(H+\frac{V_1^2}{2g}\right); \\ \text{the \textit{necessary loss},---} \\ Q\cdot\frac{V_2^2}{2g}; \\ \text{the \textit{theoretical effect or useful work}} \\ \text{\textit{per second}---} \\ Q\left(H+\frac{V_1^2-V_2^2}{2g}\right); \\ \text{the \textit{theoretical efficiency}---} \\ \dfrac{H+\frac{V_1^2-V_2^2}{2g}}{H+\frac{V_1^2}{2g}}. \end{array}\right\} \quad . \; . \; . \quad (118.)$$

(For details as to the actual efficiency and duty, and the construction of water-wheels and other hydraulic engines, see HYDRODYNAMICS.)

In *windmills*, the air, being in motion, presses against and moves four or five radiating vanes or *sails*, whose surfaces are approximately helical, their axis of rotation being parallel, or slightly inclined in a vertical plane, to the direction of the wind. The best form and proportions for windmill sails, as determined experimentally by Smeaton, are as follows (see fig. 40):—Angle of each sail with the plane of rotation; at DE . . 18°

at BC . . 7°

OD = ⅙ of *whip* OA.

$$\text{Bar DE} = \frac{OA}{5};\ \text{bar BC} = \frac{OA}{3}.$$

AC = DE.

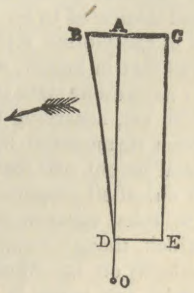


Fig. 40.

(Smeaton "On Windmills," in Tredgold's *Hydraulic Tracts.*)

168. (D.) *Heat.*—In sect. 163 the three factors into which the efficiency of an engine moved by heat can be resolved have already been stated. The efficiency of the furnace and boiler in steam-engines varies from 0·4 to 0·85. It may be considered that the loss of heat to the extent of 0·15 by the chimney, is necessary in order to produce a sufficient draught; any loss beyond this is *waste.* The theoretical efficiency of the *steam*, or *other elastic fluid* which serves as the mechanism for converting heat into mechanical energy, is regulated by a law which will now be explained.

Heat acts on bodies in two ways: to elevate temperature and make the bodies hotter, and to produce mechanical changes. Heat employed in producing mechanical changes disappears or becomes *latent*, as it is termed, and can be reproduced by reversing those mechanical changes. When a cycle of mechanical changes, ending by the restoration of the body to its original condition, produces mechanical energy, heat disappears to an amount equal to that which would be generated by employing the mechanical energy in overcoming friction; that is to say, a British unit of heat (or one degree of Fahrenheit in one lb. of liquid water) for every 772 foot-pounds of energy (being the constant already mentioned in sect. 121 as *Joule's equivalent*). This is called the *conversion of heat into mechanical energy.*

The *efficiency of the fluid* in a heat-engine is the proportion which the heat converted into mechanical energy bears to the whole heat received by the water or other fluid; and the *theoretical* or *maximum* value of that efficiency depends solely upon the respective temperatures at which the fluid receives heat and rejects the unconverted heat, according to the following law:—Let t_1 represent the temperature at which the fluid receives heat, and t_2 the temperature at which it rejects the unconverted heat, as measured from the *absolute zero;* that is, from a point 493°·2 Fahrenheit, or 274° Contigrade, below the temperature of melting ice. (Temperatures so measured are called *absolute temperatures.*) Then *maximum theoretical efficiency of the water or other fluid in a steam-engine or other heat-engine*—

$$= \frac{t_1 - t_2}{t_1} \quad . \; . \; . \; . \; . \quad (111.)$$

The necessary loss of heat by the fluid is $\frac{t_2}{t_1}$ of the whole heat received by it; and any loss beyond this is *waste.*

The theoretical efficiency of the steam in ordinary steam-engines seldom exceeds $\frac{1}{5}$th; the greatest actual efficiency is about $\frac{1}{6}$th; the efficiency in good ordinary engines is about 0·1 or 0·08, and in bad and wasteful engines 0·04, or even less. (For details, see STEAM-ENGINE.)

169. (E.) *Electricity and Magnetism.*—Electricity developed by chemical action in a galvanic battery has been to a small extent used to produce mechanical energy by alternately magnetizing and unmagnetizing soft-iron bars.

The data for determining the actual efficiency of such engines are deficient. Their theoretical efficiency depends on the following law demonstrated by Mr Joule:—

Let γ_1 denote the strength of the electric current which would be developed in the conducting wire of the battery if there were no iron bar to be magnetized; γ_2 the strength to which the current is reduced by the reaction of the iron bar, tending to induce a contrary current. Then the theoretical efficiency of the engine is

$$\frac{\gamma_1 - \gamma_2}{\gamma_1}. \quad . \; . \; . \; . \; . \quad (112.)$$

The proportion of the energy expended, which is *necessarily lost*, is $\frac{\gamma_2}{\gamma_1}$, and is employed in producing heat in the conducting circuit.

This law is exactly analogous to that of the theoretical efficiency of heat-engines given in equation 111.

There is reason to believe that electro-magnetic engines are capable of a higher efficiency than heat-engines; but the greater cost of the materials consumed renders them much less economical commercially.

170. *Transformation of Energy in General.*—The laws of the efficiency of heat-engines and electro-magnetic engines are particular cases of a general law which regulates all *transformations of energy.* (See *Proceedings of the Philosophical Society of Glasgow*, January 1853; *Edinburgh Philosophical Journal*, July 1855.)

171. *Recent Authorities.*—On the subject of applied mechanics in general the following are some of the best recent authorities:—Poncelet, *Mécanique Industrielle;* Morin, *Notions Fondamentales de Mécanique;* Moseley's *Mechanics of Engineering and Architecture;* Whewell's *Mechanics of Engineering.* Other authorities have been referred to in the course of the article. (W. J. M. R.)

MECHLIN (Flemish *Mechelen*, French *Malines*), a town of Belgium, province of Antwerp, in the midst of a rich level country on both sides of the Dyle, 14 miles S.S.E. of Antwerp. The town is well built, and has broad and clean streets, as well as a large and handsome square called the Place d'Armes. The most remarkable edifice in Mechlin is the cathedral, built in the fifteenth century, and dedicated to St Rombaud. This fine building, which is in the Gothic style of architecture, has a square tower 348 feet in height, with a fine peal of bells; and although in its present state it is nearly as high as St Paul's in London, yet, according to the original design, it was to have been surmounted by a spire which would have made the total height 640 feet. Even the present tower, however, is out of all proportion to the body of the building. The cathedral contains a picture of the Last Supper by Rubens, which, though in some respects a fine picture, is not considered on the whole to be a favourable specimen of its artist, and is not in a good state of preservation. There are several side-chapels containing pictures, of which the most celebrated is the "Crucifixion," by Vandyke, which was declared by Sir Joshua Reynolds to be not only the best of the productions of that painter, but also one of the finest paintings in the world. The pulpit is adorned with a carved representation of the Conversion of St Paul. There are several other churches in Mechlin, some of which contain pictures by Rubens. Of these, the finest is that of the "Adoration of the Magi," in the church of St John. The other remarkable buildings in Mechlin are,—the archbishop's palace, a modern edifice, which, though plain, is handsome; the Beguinage, an asylum for aged women, having a chapel with a beautiful front attached; the arsenal and cannon foundry; and the town-hall. The town also possesses a college, an academy of paintings, a society of fine arts, a botanic garden, and several charitable institutions. Mechlin has long been distinguished by the manufacture of fine lace; but this branch of industry has in the present day much fallen off, and there are now only eight houses in operation; while the lace made here is coarser and less valuable than that of Brussels. There are also manufactures of straw and felt hats, woollen and linen fabrics, oil, leather, candles, paper, &c. Mechlin possesses several breweries, and the beer which is produced is of a peculiar quality, and acquires, when kept, a flavour resembling that of wine. Among the articles for which Mechlin is famous is a sort of gingerbread, and the *déjeûner de Malines*, a dish much esteemed by epicures, made up of pigs' ears and feet, along with other ingredients.

The trade of the place is considerable; the principal articles are corn, oil, hemp, and flax, together with the various products of manufacture. The town also derives much importance from its situation on a navigable river and a canal to Louvain, as well as from being the place of junction of four lines of railway. The earliest period to which the history of Mechlin can be traced is the fifth century; when it seems to have been a place of some importance, and the capital of a lordship. It then belonged to the French. It was sacked by the Normans in the ninth century; and in 910 was given over to the Bishop of Liège. In the fourteenth century it had risen to great importance; but in after times it suffered many calamities, especially from the ravages of war. Sacked by the Spanish troops in 1572, it was again taken, six years after, by the Prince of Orange. Mechlin was captured by Marlborough in 1706, and by the French in 1746. Finally, it was again taken by the French in 1792, by whom, in 1804, its fortifications were destroyed. Pop. (1851) 30,372.

MECHOACAN, a province of Mexico. (See MEXICO.)

MECKEL, JOHANN FRIEDREICH, was born at Halle in 1781, of a family of some note in the annals of medicine. On receiving his doctor's degree at the university of his native town, he already gave evidence of the possession of distinguished talents for physical research by his inaugural thesis *De Conditionibus Cordis Abnormibus.* Having directed his attention almost exclusively to the study of comparative anatomy, he undertook travels into Germany, Italy, and France, to widen the sphere of his observation, and perfect his knowledge of his favourite science. After his return to Halle in 1809, he published a translation of the *Leçons d'Anatomie Comparée* of Cuvier, enriched with notes containing new and interesting observations. He was subsequently appointed professor of anatomy and physiology in his native university; and gave to the world in 1813 his Essay on Comparative Anatomy, which formed a fitting prelude to his great work, *System des Vergleichenden Anatomie*, 5 tom., Leipsic, 1821–31, which established Meckel's scientific reputation. In addition to various memoirs on anatomy, he likewise published a work entitled *Tabulæ Anatomico-Pathologicæ, modos omnes quibus partium corporis humani omnium forma interna atque externa à normâ recedit, exhibentes*, Lipsiæ, 4 vols. fol., 1817–26. He laboured for a long time with great industry in perfecting the excellent collection commenced by Reil, and known at the present day by the name of the *Physiological Archives* of Meckel, 12 vols. 8vo, Halle, 1815–1827. After gaining for himself a distinguished name among the most eminent scientific men of Germany, he died at Halle on the 13th of October 1833, aged fifty-two years.

MECKLENBURG, a territory of Northern Germany, lying between 53. 8. and 54. 2. N. Lat., and between 10. 40. and 13. 45. E. Long., is bounded on the N. by the Baltic, E. and S. by Prussia, and W. by Hanover, Denmark, and Lübeck. It consists of the two grand duchies of Mecklenburg-Schwerin and Mecklenburg-Strelitz; and has a total area of 5588 square miles.

1. *Mecklenburg-Schwerin* consists of a low tract of country, forming part of the plain of N. Germany. It is, however, by no means destitute of elevations or depressions; these are numerous, but not very marked; and the only hills of any importance in the duchy are those of the Ruhneburg, which separate the waters of the Elbe from those of the Baltic; but they do not exceed 600 feet in height. The duchy contains numerous lakes of considerable size, the largest of which, Lake Muritz, is 18 miles in length by 8 in breadth. The principal rivers are,—the Trave, Stepenitz, Warnow, Recknitz, and Peene, flowing into the Baltic; and the Elde and Havel, which join the Elbe. The sea-coast is not much indented, but there are a few large bays, of which the most extensive is that of Wismar. In some places the shore is steep and elevated, and in others low and sandy. The nature of the soil varies very considerably in different parts. On each side of the central ridge there is a tract of land consisting of sandy heaths and moors; near the sea, too, the country is of a sandy character; but the greater part of the surface consists of rich and fertile ground, covered in some places with large forests, and presenting in general a picturesque and lively aspect. The scenery of many of the lakes and of the sea-coast is very beautiful. Although the climate of Mecklenburg is mild, the cold in winter is severe; and the moisture of the soil and atmosphere gives rise to frequent fogs, which render the country somewhat unhealthy. The people are chiefly employed in agriculture; and the land is divided into extensive farms, which are well cultivated. The principal crops raised are,—wheat, rye, barley, oats, peas, beans, potatoes, and turnips. The timber from the forests, and which consists of oak, beech, and fir, is of excellent quality. Horses, cattle, and sheep, are numerous in the duchy, and of good breed. Mecklenburg, besides, has large herds of swine, which wander over the country; and extraordinary numbers of geese, which stock the rivers and lakes, and which supply a great part of Europe with quills, and are much esteemed for their large size and excellent quality. Minerals exist but scantily, and mines not at all, in Mecklenburg. The manufactures consist chiefly of linen and woollen stuffs; while there are also breweries, distilleries, cotton factories, paper-mills, &c.; but although encouraged by the government, they are on the whole unimportant. The trade of Mecklenburg is of more value, and consists in the export of agricultural and manufacturing produce. This flourishing condition of commerce is to be ascribed in a great measure to the favourable position of the country between the Baltic and the Elbe, and to the comparative freedom of the trade from the restrictions of duties and imposts. The peasantry were till a recent period in a state of serfdom, such as was common throughout Europe in the middle ages; but the last trace of this disappeared by law in 1820, and in fact in 1825. A great part of the inhabitants are nobles; but of these the greater number, though "proud of pedigree, are poor of purse," and are obliged to condescend often to the most menial employments to gain a livelihood. The executive power of the duchy is in the hands of the sovereign; and the legislature consists of two estates—the landowners, amounting to about 572; and the deputies of the 44 towns, who are more than 200 in number. This body forms the legislature of the two duchies together, and meets annually, alternately at Sternberg and Malchin. They have, however, no power to originate motions, but must decide on the proposals submitted to them by the sovereign. The established religion, and that of the majority of the people, is Lutheran; there are, however, a few Calvinists, Romanists, and Jews. The duchy contains a university at Rostock, and many public schools throughout the country. The revenue of Mecklenburg-Schwerin for the year ending June 1854 amounted to L.480,193, and the expenditure to L.500,211. Pop. (1854) 538,997.

2. *Mecklenburg-Strelitz* is distinguished by the same general physical features as the other duchy. The surface, however, is in general lower than Mecklenburg-Schwerin; and the inhabitants are, like those in the adjoining district, chiefly employed in agriculture. The government is of the same nature as that of Mecklenburg-Schwerin, with which it is very closely connected; and the two duchies together hold the fourteenth place in the German Confederation, and have a single vote in the Select Council. In the full diet, however, Mecklenburg-Schwerin has two suffrages, and Mecklenburg-Strelitz only one. Pop. (1851) 99,628.

The most ancient inhabitants of Mecklenburg were the

Vandals, who afterwards migrated southwards, and the country was taken possession of by the Obotriti and other Slavonic nations. The ancestor of the present ducal family of Mecklenburg was Pribislav, who was made a prince of the empire by Charles IV. in 1340. Mecklenburg was afterwards given by Ferdinand II. to Wallenstein, and was conquered in more recent times by Napoleon; but the reigning family was always restored, and in 1815 assumed the title of Grand Dukes. The House of Mecklenburg is thus one of the most ancient in Europe; and by the marriage of a princess of that family to George III. of England, is connected with the royal family of Great Britain.

MEDALS. See Numismatics.

MEDE, Joseph, a learned English divine, was born at Berden in Essex in October 1586. While attending school at Wetherfield in his native county, he taught himself Hebrew from a copy of Bellarmine's Grammar, which he had picked up during a visit to London. He entered Christ's College, Cambridge, at the age of sixteen, and took his degree of M.A. in 1610. At this time his accomplishments and his devotion to study might have set him on a fair road to church preferment; but, passionately fond of academic retirement, he settled down contentedly in a fellowship which he obtained through the interest of Bishop Andrews. Soon after this he was appointed reader of the Greek lectures of Sir Walter Mildmay's foundation, an office which he occupied till his death. The time not occupied with these duties was spent in the study of history, both sacred and profane, and in applying his acquisitions in that branch of knowledge to the elucidation of Holy Writ. In 1618 he took the degree of Bachelor of Divinity, and modesty alone prevented him from taking that of Doctor. In 1627 Archbishop Usher paid a tribute to his learning and worth by recommending him to the provostship of Trinity College, Dublin; but this appointment Mede declined, nor had he altered his mind when the offer was repeated in 1630. Not less remarkable for piety than for learning, he was a strenuous promoter of the design for the universal pacification among Protestants; and he regularly devoted a tithe of his income to charitable and pious purposes. He died in October 1638.

Mede's principal work is his *Clavis Apocalyptica*, published in 1627, and translated into English in 1643. According to Bishop Hurd, it was the first rational attempt to interpret the Apocalypse. A collection of Mede's works was published, with a Life by Dr Worthington, in 1 vol. folio, London, 1672.

MEDEA, a celebrated sorceress in Greek mythology, was the daughter of Æetes, King of Colchis. Her mother is variously supposed to have been Idyia, Eurylyte, Hecate, and Antiope. (Apollod. i., Schol. Apollon. iii., Schol. Hesiod. 957, Hygin. 25.) Medea first appears in fabulous history at the time when the Argonauts landed in her father's kingdom. She then became enamoured of Jason, the leader of the expedition, and promised him her assistance on condition that she should become his wife and return with him to Greece. By her magical arts the Golden Fleece, the object of the enterprise, was obtained, and she set sail with her betrothed in the ship Argo. Æetes, however, gave chase, and was on the point of overtaking the fugitives, when Medea murdered her brother Absyrtus, tore him to pieces, and strewed the sea with his bleeding limbs. The father tarried to gather up the remains of his son, and his daughter escaped, and continued on her course towards Iolcus, the native city of her husband. On arriving at the land of the Phæacians, the Argonauts and their companions were overtaken by the Colchians, who demanded the restoration of Medea. The case was then brought before Alcinous, King of Phæacia, who decided that Medea must be given up unless she was married to Jason; but, by the assistance of his wife Arete, the marriage was hurriedly performed, and Jason was allowed to take his wife with him to Iolcus, without any further delay or hinderance. There Jason learned for the first time that his brother had been murdered, and that his father and mother had been driven to commit suicide by the ruler Pelias. He therefore called upon Medea to employ all her arts for the purpose of revenge. The sorceress summoning the daughters of Pelias, showed them by actual experiment how an animal might be restored to youth by being seethed in a cauldron, and persuaded them to try the same process on their aged father. The limbs of Pelias failed to be revived, and thus the revenge of Jason was glutted. Owing to this barbarous deed, Medea and her husband were forced to quit Iolcus. Another version of the story is given by Ovid, who relates that on his return to Iolcus, Jason found his father Æson still alive, and that he was restored to youth by the arts of Medea. Medea and Jason then fled to Corinth, and there, after the lapse of ten years, Jason fell in love with Glauce or Creusa, daughter of Creon, King of Thebes. Full of revenge at being thus deserted, Medea presented her rival with a poisonous garment, which, as soon as it was put on, consumed its new owner to ashes. She then killed her own sons, Pheres and Mermerus, and escaping from the enraged father, fled through the air in a chariot drawn by winged dragons. Alighting at Athens, she underwent the purification for murder, and was then married to King Ægeus. In no long time, however, she began to plot the destruction of Theseus, the son of her husband by a former marriage; but her intentions having been discovered, she was again compelled to mount her airy chariot and flee. According to one account, she repaired to Asia and gave to the nation of the Medes their name. (Paus. ii., Ovid. *Met.* vii.) But other authorities state that she returned to her native Colchis, and, with the aid of her son Medus, restored her father Æetes to his throne. (Apollodor. i.) Medea is also said to have become latterly reconciled to Jason. (Tacit. *Ann.* vi.) After death she was married to Achilles in the Elysian Fields. (Schol. Apollon. iv.) The story of Medea is the subject of several tragedies. Those of Euripides and Seneca are the most famous.

MEDELLIN, a city of South America, capital of a province of the same name, in the department of Cundinamarca, New Granada, is situated on the Porse, a small affluent of the Cauca, 40 miles S.E. of Antioquia. It carries on a considerable trade in the products of the district; and had in 1851, 14,800 inhabitants.

MEDGYES, Mediasch, or Medwisch, a royal free town of Transylvania, capital of a district of the same name, stands on the left bank of the Great Kokel, 38 miles E. of Carlsburg. It is surrounded by walls, with six gates; and has a Roman Catholic, Calvinistic, and Greek churches, a Franciscan monastery, and a gymnasium with small library. It has some trade in wine, the produce of the district. Pop. 6200.

MEDIA, a country in the western part of Asia, was bounded, according to Ptolemy, on the N. by part of the Caspian Sea; on the S. by Persia proper, Susiana, and Assyria; on the E. by Parthia and Hyrcania; and on the W. by Armenia and Assyria. It was anciently divided into the provinces of Tropatene, Charomithrene, Darites, Marciane, Amariace, and Syro-Media. In a later division, however, all these were reduced to two—*Media Magna*, and *Media Atroptia*, or *Atropatene*. Media Magna was bounded by Susiana, Parthia, Hyrcania, the Caspian Sea, and Atropatene, and contained the cities of Ecbatana, Hamadan, Laodicea, Ragæ, &c. The greater part of Media Magna is lofty and mountainous, with a cold climate, especially in the northern parts. The southern region, however, consisting of plains and valleys, was in the time of

Strabo productive of all sorts of vegetables, except the olive. This region was also celebrated for its pasturage and for its horses; the Nisæan plain especially being devoted to the rearing of those animals, and containing the royal herds of the Persian monarchs, amounting, it was said, to no less than 50,000 in number. This country, in addition to the money tribute, supplied to the Persian empire 30,000 horses, 40,000 mules, and 100,000 sheep; so great at that time were its pastoral riches. (Strabo, xi., p. 525.) Media Atroptia, or Atropatene, lay between the Caspian Mountains and the Caspian Sea. Media derived its name from Madai, the third son of Japhet; as is plain from Scripture, where the Medes were constantly called *Medai*. Amongst profane authors, Strabo derives the name from Medus, the son of Jason and Medea, others from Medea herself, and some from the *medial* position of the country. Sextus Rufus tells us that in his time it was called *Medena;* and from Herodotus we learn that its inhabitants were called *Arii*.

The government of the various tribes into which the country was divided was originally monarchical, and they seem to have had their own kings even in the earliest times. They were first brought under a foreign yoke by Pul, said to have been the founder of the Assyrian monarchy, or by his immediate successor Tiglath-Pileser. From the time of Pul, or Tiglath-Pileser, who succeeded his father in the year 740 B.C., they remained subject to the Assyrians till about the latter end of the reign of Sennacherib, 710 B.C., when, emancipating themselves from Assyrian bondage, they fell into a state of anarchy. It was accordingly found necessary to appoint a king; upon which Dejoces was named to the sovereignty, and with universal applause placed upon the throne 710 B.C. No sooner had he been vested with the supreme power, than he threw off the mask and became a tyrant. Ecbatana was built and chosen for the royal residence, and a stately palace was erected. Dejoces having enacted various laws for the government of the kingdom, and having in a considerable degree civilized his unpolished subjects, entertained thoughts of extending the limits of his new kingdom, and with this view he invaded Assyria. Nebuchodonosor, however, at that time king of Assyria, met him in the plain of Rhagæ, and a battle ensued, in which the Medes were utterly defeated, and Dejoces was slain, after a reign, according to Herodotus, of fifty-three years. The Assyrian king, following up his success, reduced several cities of Media, and almost utterly destroyed Ecbatana. Dejoces was succeeded by his son Phraortes 647 B.C. This prince, not satisfied with the kingdom of Media, invaded Persia, and is said to have brought that nation under subjection. Such is the account of Herodotus. Others, however, ascribe the conquest of Persia, not to Phraortes, but to his son and successor Cyaxares. Phraortes, however, subdued several neighbouring nations, and made himself master of almost all Upper Asia, lying between Mount Taurus and the River Halys. Emboldened by his success, he invaded Assyria, subdued a great part of the country, and even laid siege to Nineveh, the metropolis. He fell before that city in the twenty-third year of his reign.

His son Cyaxares was not less valiant and enterprising than his father, and had better success against the Assyrians. With the remains of that army which had been defeated under Phraortes, he not only drove the conquerors out of Media, but obliged Chyniladan to shut himself up in Nineveh. To this place he immediately laid close siege; but was obliged to abandon the enterprise on account of an irruption of the Scythians into his own country. Cyaxares engaged these new enemies with great resolution, but was utterly defeated; and the conquerors overran not only all Media, but the greater part of Upper Asia, extending their conquests into Syria, and as far as the confines of Egypt. They continued masters of this vast tract of country for twenty-eight years, till at last Media was delivered from their yoke by a general massacre at the instigation of Cyaxares.

The Medes afterwards encountered the Lydians; and during the engagement there happened a total eclipse of the sun, which is said to have been foretold by Thales the Milesian. Both nations were terrified, and soon afterwards concluded a peace by the mediation of Nebuchadnezzar, King of Babylon, and Syennesis, King of Cilicia. This peace was confirmed by the marriage of Aryenis, the daughter of Halyattes, and Astyages, the eldest son of Cyaxares; and of this marriage was born in the ensuing year Cyaxares II., who, in the book of Daniel, ch. v. 31, is called Darius the Mede. Cyaxares, disengaged from the Lydian war, resumed the siege of Nineveh; and having formed a strict alliance with Nebuchadnezzar, King of Babylon, they joined their forces, and took and destroyed the city (606 B.C.). With this prosperous event commenced the great successes of Nebuchadnezzar and Cyaxares; and thus was laid the foundation of the two collateral empires, as they may be called, of the Medes and Babylonians, which rose upon the ruins of the Assyrian monarchy. After the reduction of Nineveh, the two conquerors led the confederate army against Pharaoh-Necho, King of Egypt, defeated him near the Euphrates, and compelled him to resign what he had formerly taken from the Assyrians. After this victory they reduced all Cœlesyria and Phœnicia; they then invaded and laid waste Samaria, Galilee, and Scythopolis; and at last besieged Jerusalem, and took Jehoiakim prisoner. Nebuchadnezzar afterwards pursued his conquests in the West, and Cyaxares subdued the Assyrian provinces of Armenia, Pontus, and Cappadocia. Again uniting their forces, they reduced Persia and Susiana, and accomplished the conquest of the Assyrian empire. The prophet Ezekiel (ch. xxxii. 22, &c.) enumerates the chief nations who were subdued and slaughtered by the two conquerors Cyaxares and Nebuchadnezzar.

After this victory the Babylonian and Median empires seem to have been united; but upon the death of Nebuchadnezzar, or rather towards the close of his life, a war ensued, which was only extinguished by the dissolution of the Babylonian empire. The Medes, under Astyages, the son of Cyaxares I., withstood the power of the Babylonian monarchs, and, under Cyrus and Cyaxares II., utterly destroyed their empire by the taking of Babylon. After the death of Cyaxares II. the kingdom fell to Cyrus, by whom the seat of the empire was transferred to Persia. After the time of Cyrus, the union between the Medes and Persians became so close that many of the customs of the latter are believed to have been derived from Media; and the name by which the Persians were known to the Greeks was that of Medes, while in sacred history they are always called Medes and Persians. On the dismemberment of the Persian empire they came under the dominion of the Seleucidæ, and subsequently of the Parthians.

The Medes were fond of equestrian exercises, and were great adepts in archery. The priests of the Median religion were called *Magi;* and the principal objects of worship were the sun, moon, and five planets. The seven concentric walls of Ecbatana, the capital, were, according to Herodotus, decorated with various colours, which were probably symbolical of these objects of adoration; and the correctness of this description has been recently confirmed by the discovery of similarly coloured terraces at Birs Nimroud, near the ruins of Babylon.

MEDICAL JURISPRUDENCE.

History.

The connection between medicine and legislation had been perceived long before it was considered as a peculiar branch of study, or had even obtained a distinctive appellation. Since its importance has been recognized, it is known in Germany, the country in which it took its rise, by the name of STATE MEDICINE; in Italy and in France it is termed LEGAL MEDICINE, and with us it is usually denominated MEDICAL JURISPRUDENCE, or FORENSIC MEDICINE. It is founded on the relations which ought to subsist between human nature and social institutions, and consists in the application of the principles of medical science to the administration of justice, and to the preservation of the public health. Its nature and objects will be best elucidated by a sketch of its progress.

HISTORY OF LEGAL MEDICINE.

Notwithstanding the importance of the objects which it embraces, and their intimate relation to the interests of society, the true origin of Medical Jurisprudence is of comparatively recent date. It is true that traces of its principles may be perceived in very remote times. In the Mosaic institutions the judges are enjoined to consult the *priests*, who were the sole physicians of that age and country, on the modes of distinguishing leprosy from other diseases, on the marks of defloration, and the examination of wounds. In the slight notices handed down to us of the ancient code of Egypt, attributed to Menes, we may observe one trace of the influence of medicine on legislation, in the law which forbade the infliction of corporal punishment on a pregnant female; but among the ancient states of Greece the principles of medical science, though successfully cultivated, seem scarcely to have been applied to legislation, except in certain questions respecting the legitimacy of children, a subject on which the notions even of Aristotle were not very definite. In the writings of Galen, however, we find more distinct traces of legal medicine; as in his various remarks on the difference between the lungs of a fœtus and of an adult, in his treatise on simulated diseases, and in his observations on the legitimacy of seven months' children.

The laws of ancient Rome were borrowed from Greece, and we could scarcely expect to find in them a more refined legislation; but it is worthy of notice, that the laws of the Twelve Tables fix on 300 days as the extreme duration of utero-gestation, the precise term fixed by the Code-Napoleon. Some writers contend that the Roman law authorized the inspection of dead bodies by medical men, because of the twenty-three wounds by which Cæsar fell, the physician Antistius pronounced one only mortal; and because Tacitus has spoken of the marks of poison on the bodies of Germanicus and Agricola: yet we have no proof that such opinions were required by any positive law, or that the judge was in the habit of demanding the assistance of the physician. In the Justinian code, however, we find more obvious traces of the relation between medicine and law; as in the titles *De statu Hominum; De Pœnis et Manumissis; De Sicariis; De Inspiciendo ventre Custodiendoque partu; De Muliere quæ peperit undecimo mense; De Impotentiâ; De Hermaphroditis:* yet in the Justinian code it was not by the testimony of living medical witnesses that such quesions were to be decided, but "on the authority of the learned Hippocrates."

History.

It was chiefly on questions of medical police, as to what regarded the salubrity of cities and stations, that the ancient Greek or Roman magistrates had recourse to medical assistance; and it appears that it was to such subjects that the public functions of the *Archiater* of the lower empire were confined.

Medical Jurisprudence, as a science, cannot date farther back than the 16th century. Various German emperors had in vain attempted the introduction of an uniform criminal code; but George, bishop of Bamberg, in 1507, proclaimed a penal code, drawn up for his states by *Baron Schwartzenberg*, in which the necessity of medical evidence, in certain cases, was recognized: and though this improvement was for some time resisted by the greatest part of Germany, the emperor Charles V. eventually succeeded in persuading the diet of Ratisbon, in 1532, to adopt a uniform code of German penal jurisprudence, founded on that of Bamberg, in which the civil magistrate was, in all cases of doubt or difficulty, enjoined to obtain the evidence of medical witnesses; as in cases of personal injuries, infanticide, murders by poison or other means, pretended pregnancy, simulated diseases, &c. The celebrated *Constitutio Criminalis Carolina* was published in 1553; this must be considered as the true dawn of Legal Medicine, and Germany the country which gave it birth. To the same country must be ascribed the glory of having first thrown the shield of medical science over the victims of a dark fanaticism. The belief in the powers of witches and sorcerers was in full force in the 16th century. It is computed that in Lorrain above 900 persons were burnt alive within 19 years, for the imputed crime of sorcery; and that in the Electorate of Treves alone, within a few years, 6500 individuals had perished in the flames for the same imaginary crime. In Germany and France instances of pretended demoniacal possession were perpetually occurring; and at Freidberg public prayers were offered up to assuage that dire affliction. Weiher, physician to William, duke of Cleves, had the boldness to impugn these superstitious notions, in a tract published at Basle in 1564, and undertook to prove that witches and demoniacs ought to be considered as unhappy persons subject to hypochondriasis and hysteria, whose maladies should rather excite pity, than render them obnoxious to punishment; while he ridiculed the ordinary modes by which these unfortunate beings were proved to be guilty of the alleged crimes. This attack on a popular superstition aroused alike indignation and vengeance against the daring innovator; and, but for the powerful intercession of his patron, Weiher himself would have perished in the flames, from which he had tried to save others.

In the close of that century many treatises on different branches of Legal Medicine appeared in various countries. Ambrose Paré wrote on monstrous births, on simulated diseases, and a memoir on the art of drawing up medical reports. In 1598 Severin Pineau published at Paris the treatise *De Notis Integritatis et Corruptionis Virginum;* a book still quoted as an authority. The first *system of Legal Medicine* appeared about the same time in Sicily, in the work of Fortunato Fidele *De Relationibus Medicorum;* in which, as might be expected in his age and country, the opinions of the physician are too much warped by his servile deference for the canon law and its clerical expounders.

The rapid progress of anatomy in the commencement of the 17th century now became apparent in the invaluable *Quæstiones Medico-Legales* of Paulo Zacchia, which appeared in successive volumes from 1621 to 1635; a work which will ever be regarded as a landmark in the history of Legal Medicine; and which, by its learning and its sagacious indications, in an age in which chemistry was in its infancy, and physiology very imperfect, places the medical acumen of the great Roman medico-jurist in a very favourable point of view.

The noble discovery of the circulation of the blood gave a new light to physiological reasoning, which was broadly reflected on Legal Medicine: and to Harvey we also owe the idea how the application of Galen's remark, respecting the difference between the adult and the fœtal lungs, might be applied to elucidate cases of infanticide.

About the same time appeared two valuable treatises by Melchior Sebiz, *De Notis Virginitatis*, and *Examen Vulnerum*. In the first he maintained that the existence of the hymen was the real mark of virgin purity; an inference warmly denied by Orazio Augenio and Pietro Gassendi: in the second he pointed out the importance of distinguishing between wounds *incidentally* and *necessarily* fatal.

In 1663 Thomas Bartholin, a Danish physician, carefully investigated the period of human utero-gestation, and proposed the *Hydrostatic Test*, or observing whether the lungs of the infant floated or sunk in water, as proving whether it had ever breathed. The rationale of this process was more fully explained by Swammerdam in 1677; but was first applied to practical use by Jan Schreyer in 1682; after having been investigated by Thruston and Rayger.

While these important steps were in progress, Germany set the example of the first public prelections on Medical Jurisprudence. About the middle of the 17th century, Michaelis gave the first course in the university of Leipzig: these were soon followed by the lectures of the celebrated Bohn, who, before the close of the century, had published his valuable works *De Renunciatione Vulnerum, et Dissertationes Medicinæ Forensis*, which were speedily succeeded by the tract *De Officiis Medici Duplicis, Clinici et Forensis*. The two first were nearly contemporary with the investigations of Welsch and Amman *on the fatality of wounds*, and the celebrated work of Licetus *De Monstris*; and the latter with the valuable *Sepulchretum* of Bonnet.

The mode of conducting medico-legal investigations had attracted attention in France, from the time of Ambrose Paré, through the 17th century. French authors love to trace the rudiments of the science in their country from the 12th century, in the rules given in the *Assizes of Jerusalem*, for drawing up exemptions from certain civil and military duties, and in several subsequent ordonnances of their monarchs, for the inspection of wounds: enactments from which we may trace the institution of the *Chirurgiens du Châtelet*. In 1603 Henri IV. authorized his physician to appoint persons, skilled in medicine and surgery, to make judicial inspections and reports in all cities and royal jurisdictions. The difficulty of carrying this into effect induced Louis XIV. to create, in 1692, *hereditary royal physicians and surgeons*, for the same purpose, with various immunities and privileges; but their corruption and venality soon became notorious, and the office was suppressed in 1790.

Various decrees, however, of the parliament of Paris, from the middle to the end of the 17th century, were directed to the improvement of legal medicine; and that body acquired great celebrity by the general equity and good sense of its judgments. Notwithstanding this auspicious commencement, Legal Medicine did not then flourish in France; and the work of Gendry, *Sur les Moyens de bien rapporter à Justice*, shews how imperfect were the then approved modes of investigation; though it proves that the importance of the subject began to be acknowledged. No other French work on Legal Medicine appeared in that century, with the exception of *Doctrine des rapports en Chirurgie* of Blégny, which was superseded in the beginning of the succeeding century by the more useful *L'art de faire des rapports en Chirurgie* of Devaux.

The 18th century commenced with happier auspices for our science, and the press teemed with important works on Legal Medicine. As early as 1700 the admirable treatise on the diseases of artificers by Bernardino Ramazzini appeared at Padua. In the following year Valentini published his *Pandectæ Medico-legales*; his *Novellæ* appeared in 1711; and both were incorporated in the excellent *Corpus Juris Medico-legale* in 1722. This work contains a judicious view of all that had been done before him, and is a vast storehouse of medico-legal information.

Several professorships for teaching this subject were about that period founded in the German universities; and the succession of German writers becomes now so numerous that we cannot attempt to give a catalogue, far less to characterize their works. Zittman, Boerner, Kannegeiser, and Teichmeyer, each published systems of various yet acknowledged merit. The *Institutiones Medicinæ Legalis* of the latter long formed the manual of the student: the clear and forcible reasoning of Storch in his work *De Medicinæ Utilitate in Jurisprudentia* (1730), vindicated the high importance of this branch of knowledge: but the *Systema* of Alberti, professor of Legal Medicine at Halle, in six quarto volumes, was the most complete and laborious work ever published on this subject. The writings of this learned man are obscured by his attachment to the mysticism of the Stahlian school; yet the industry with which he has collected facts renders his work a precious mine of information. Curious additions to our knowledge were made by the smaller publications of Loewe, Richter, Budæus, Troppanneger, Fritch, and Wolff, Hermann, Clauder, Herzog, and Parmeon; which are chiefly valuable to those who may be called to exercise the profession in Germany. In the *Bibliothèque Medicale* of Ploucquet will be found the names of those who have dedicated themselves to the illustration of particular branches of this extensive subject; and in the *Collectio Opusculorum* of Schlegel will be found some of the best detached treatises of the first three-fourths of the last century on the subject of wounds, poisoning, infanticide, utero-gestation, insanity, and the legal inspection of dead bodies. About the same time appeared the *Anthropologia Forensis* of Hebenstreit, the *Specimena* of Fursteneau, the *Institutiones* of Ludwig, and the *Elementa* of Fazelius. The lectures of Haller belong to this same period, though they were not published till 1781–2. Towards the close of the last century, the Germans were almost the only successful cultivators of Medical Jurisprudence. The *Elementa* of Plenck appeared in 1781, and the book is still considered a good introduction to the study. The *Bibliothek* of Daniel appeared in 1784; and in it we find the name of *state medicine* given to this branch of knowledge. Between 1790 and 1800, appeared the *Conspectus* of Sikora, the *Handbuch* of Loder, the *System* of Metzger, and the *Entwurf* of Müller.

During the last century little was done in Italy after the time of Ramazzini; and in France the subject had attracted little attention, until the celebrated case of Villeblanche called forth the memoir of Louis on the period of utero-gestation, in which he attacked the pretended instances of protracted pregnancy with powerful arguments, which were seconded by Astruc and Bouvart, but vehemently opposed by Le Bas and Antoine Petit. This controversy gave rise to many able publications, in which Pouteau and Vogel took part; but victory remained with Louis and his adherents.

Louis wrote also a valuable memoir on the anatomical examination of bodies found hanged; he pointed out the mode by which we are able to distinguish assassination from suicide in such circumstances. He applied them to the celebrated cases of Calas, of Syrven, Montbaillet, and Baronet, in which are models of medico-legal investigation; and he may be considered as the first who publicly taught in France the just application of medical knowledge to jurisprudence.

The subject of poisoning was examined by Sallin, in a case where a person had been buried sixty-seven days; and he made a very ingenious attempt to investigate the effects of poisons; but has sometimes substituted speculation for facts.

In 1789 professor Chaussier read his excellent *Memoire* before the Academy of Dijon; in which he shewed the necessity of careful inspection by the medical witness in all cases of death from blows or wounds, and gave admirable models of medico-legal reports. Next year he delivered a course of lectures on Legal Medicine to numerous pupils. The last year but one of the last century gave to the world the very excellent *Traité de Medecine Legale* of Foderé.

It may excite surprise that in this sketch we have made no mention of British authors. The fact is, that with the exception of the short Elements of Medical Jurisprudence published by Dr. Samuel Farr in 1788, which is little else but an abridgement of Fazelius, there was no treatise on Forensic Medicine in the English language.

It is true that some medico-legal questions are ably but incidentally treated in the writings of Mead, Monro, Denman, Percival, and John Hunter, and that an interesting Essay was published by Dr. Wm. Hunter "On the uncertainty of the signs of murder in the case of bastard children;" but the importance of the study, as a whole, was not understood in this country till long after the publication of many valuable systems in Germany, Italy, and France.

In the present century France took the lead. The end of the last century was marked by the institution of three professorships of Forensic Medicine. Mahon was the first French professor, and his reputation as a teacher gave him a name, which the posthumous publication of his lectures has not sustained. The short *Cours de Medicine Legale* of Belloc appeared in 1802. Tartra's excellent Essay on *Poisoning by Nitric Acid* was published in the same year, between which and the year 1810 various short treatises appeared, chiefly on detached branches by Achart, Drouard, Lavort, Masson, Faulaure, Desortieux, Vigné, Lamarre, Banc-Cavé, Godemar, Raffenaut, De Lisle, and Faure.

In 1814 appeared the important *Toxicologie* of Orfila, (a Spaniard naturalized in France), which has changed the face of this part of Medical Jurisprudence, by the number of experiments, the original views on the nature and action of poisons, and the disquisitions on the modes of detecting them, it contains. The French practitioner may consult with advantage the *Manuel* of Bertrand, published in 1817; and the admirable *La Medecine Legale relative à l'art des Accouchemens* of Capuron, has scarcely left us any thing to desire on this branch of the subject. In 1819 appeared the excellent Essays of Lecieux on *Infanticide*, of Renard on *Medico-legal examinations of dead bodies*, of Laisne on *Perforations of the Stomach*, and of Rieux on *Ecchymosis, Suggillation* and *Contusion*, in the same volume. Valuable detached essays by Foderé and Marc are contained in the *Dictionnaire des Sciences Medicales:* and we may close our French list with the *Manuel* of Briand and Brosson, republished in 1828; the *Secours à donner aux Asphyxiées* of Orfila, which appeared in 1833; and the useful *Manuel Complet* of Sedillot.

During the present century Germany has not been idle. We have good compends by Schmidmüller, Masius, and Willberg. Rose published a very valuable essay on *Medico-legal Dissection*, which has been translated and enlarged by Marc, (Paris, 1808); and an excellent treatise on *Pharmaco-chemico-Medical Police*, was given to the world by Remer. This last treatise has been translated into French by Lagrange and Vogel, in 1816. Among many works which have appeared in Germany of later years, connected with our subject, we may mention the curious collection of cases by Von Fuerbach, published in 1828, entitled *Merkwürdiger Verbrechen*—Remarkable Crimes; the little tract of Drs. Bunsen and Berthold, on the power of *Hydrated Peroxide of Iron as an antidote for Arsenic*, which appeared at Göttingen in 1834; the *Contributions to Legal Medicine* of Bernt; and the masterly analysis of various poisons, by Buchner and Herberger.

Only two medico-legal works of any consequence have proceeded from the press of Italy within the present century: the *Instituzione di Medicina Legale*, by Tortosa of Vicenza, and the *Medicina Legale* of Barzellotti.

Medical Jurisprudence may fairly be said to have only commenced in Britain within the present century. The first lectures ever delivered in Britain were given in the University of Edinburgh, in 1801, by the elder Dr. Duncan; and the first established Professorship was conferred by government on his son in 1803, since which period it has been regularly taught in that seminary.

The first original British work on Medical Jurisprudence was Dr Male's *Epitome of Juridical or Forensic Medicine, for the use of Medical Men, Coroners, and Barristers*, which appeared in 1816; and, though a short sketch, it contains interesting notices of English cases, and English law. *Medical Jurisprudence, as it relates to Insanity, according to the Law of England*, was published, in 1818, by Dr Haslam, in a little volume, illustrated by original cases. But the most valuable work then presented to the public, in an English dress, was the *Principles of Forensic Medicine* of Dr Gordon Smith; a volume commendable as an elementary treatise, less diffuse than most of the continental systems, and interesting to the British practitioner, by the numerous references to British cases and to our national codes. In 1820 Dr. William Hutchinson published his useful dissertation *on Infanticide*, in which its relation to physiology and Jurisprudence is very ably considered. These works were soon followed by the more costly publication of Paris and Fonblanque, in three octavo volumes; in which, among some matter little interesting to the general student, are important references to English Jurisprudence.

The last British work we shall mention is the admirable *Toxicology* of Professor Christison, which appeared first in 1829, and has since gone through a second, a third, and a fourth edition; a work the most philosophical and perfect which has yet appeared on the subject of poisons.

It would be improper to pass over the labours of our trans-atlantic brethren in this branch of science. In 1819 Dr Cooper of Philadelphia republished in America the treatises of Farr, Male, and Haslam, with *the remarks* of Mr Dease, intended for the information of juries and young surgeons; a letter originally addressed "to the Chief Justice of Ireland, by a surgeon of that country." Dr Cooper added some notes, and a good digest of the laws relating to insanity and nuisance. Four years afterwards the American press presented us with the excellent work of Dr Beck, which is a compend of all known on the subject. The author has freely availed himself of the writings of his predecessors; but his references to original authorities are copious and correct; and we must consider the last edition as the best work, on the general subject, which has appeared in the English language. We may here also notice the smaller works, *Outlines of Medical Jurisprudence*, by Professor Traill, and the *Manual of Medical Jurisprudence* of Dr Alfred Taylor.

Medical Jurisprudence may be divided into two great branches, *Forensic Medicine*, and *Medical Police*. The first may be conveniently subdivided into, 1st, Questions affecting the civil rights, or social duties of individuals; 2d, Injuries to Property; 3d, Injuries to the person. The second part may also be subdivided into, 1st, Questions affecting the preservation of individuals; 2d, What relates to the health of men collected into communities.

It is obviously impossible, in the limits of a dissertation of this nature, to do much more than allude in general terms to most of the subjects included under these branches.

PART I.—FORENSIC MEDICINE.

SECTION I.—QUESTIONS AFFECTING THE CIVIL OR SOCIAL RIGHTS OF INDIVIDUALS.

Development of the Body.

I.—Development of the Human Frame.—The usual development of the corporeal and mental powers becomes of high importance in establishing personal identity, in determining criminal responsibility, and in giving validity to various civil contracts.

1. *Infancy* is the period from birth until the completion of the seventh year; and its progress is best determined by attention to the size of the body, the evolution of its proportions, and the state of the first teeth. Its conclusion is marked by the loss of the milk incisors, and coming of the first permanent teeth.

2. *Childhood* may be considered as extending from the last period to the 14th or 15th year, or the commencement of puberty. The expansion of the body, the state of the teeth, and of the genitals, are its principal characteristics.

3. *Adolescence* is marked by changes in the whole constitution, by the commencement of the beard in males, and of the catamenia in females; this is of uncertain duration, but may be considered, with us, as extending to the 17th or 18th year.

4. *Youth* is the period between adolescence and the full perfection of the bodily powers. In it the generative function is perfected. We may consider it as terminating with the age of legal majority, though probably it should be extended to the 25th year, as it is with some nations.

5. *Virility* is that period during which all the bodily powers are perfect, and the mental faculties are matured. It has no definite bounds in man; but the perfection of the bodily powers of the female may be considered as bounded by the time when the catamenia cease, or woman is incapable of being a mother. That period is usually about her 45th year. It is during this period that all the bodily and mental faculties have generally acquired their full perfection in both sexes.

6. *Old Age* has no absolute beginning, fixed by nature, except in what we have just noticed of the female. It is exceedingly difficult to ascertain the age of persons of either sex in this period of life, so that no general rule can be fixed, and the limits of old age on either hand cannot be determined. Its general characteristics are stiffness of the limbs, wrinkling of the skin, loss of teeth, blanching of the hair, impaired vision, and decay of all the bodily faculties. Its approaches are often marked by the appearance of fan-like wrinkles at the outer canthus of the eye, by increased obesity, and by the shoulders becoming round.

7. *Decrepitude* is the last stage of human existence, in which the bodily vigour is decayed; the knees and spine are curved, from the inability of the muscles to support the weight of the superior parts of the body, or by alterations in the form of the cartilages; the senses are blunted; and the only refuge is the grave. The periods at which these various changes take place are accelerated and retarded by constitution, climate, food, habits, education, and occupation.

Duration of Life.

II.—Duration of Human Life.—The ordinary chances of human life are an important subject of inquiry, deduced from accurate comparisons of registers of births and deaths. On this is founded the system of annuities, the principles of benefit societies, and of insurances on lives. Unfortunately these registers have been so ill kept in Britain, that our own tables have generally been calculated from foreign registers, especially those of Sweden and Finland. It is well known that Dr Price's calculations, from the Northampton tables, gave far too high a rate of mortality; and have caused much loss to the nation, in the payment of public annuitants. The later tables, calculated from the last Swedish and Carlisle registers, have proved this most decisively; and the labours of Messrs. Milne, Lyon, and Finlaison have since furnished us with surer data for our calculations of probabilities of survivorship, and the payment of benefit clubs. The important questions connected with this subject, and the light which a better system of registration is capable of throwing on many subjects connected with population, and the progress of medical knowledge, the important civil rights of individuals involved in the accuracy of registers of births, marriages, and deaths, has induced the government to take up the whole question of registration, and place it on a public and permanent footing.

Personal Identity.

III.—Personal Identity.—To those little familiar with such inquiries, the danger of mistaking one person for another will not appear very considerable; but the fatal errors which have arisen from this source are too well known in the jurisprudence of every country. It becomes, therefore, of consequence to point out the circumstances by which personal identity may be rendered doubtful, and to indicate the marks by which it is best established. The first may include the effects of age, climate, aliment, habits, passions, wounds, diseases, &c. The circumstances which chiefly enable us to identify one long absent from his native country are, accurate observation of his likeness to his family; his resemblance to what he once was; in some instances his dialect; his recollection of past events; but, above all, the occurrence of scars, or *nævi materni*, known to have been on the individual in question.

Marriage.

IV.—Marriage.—Under this head the principal business of the medical jurist is with the nubile age, according to nature, and legislative enactments; and with physical circumstances affecting the legality of marriages, which may justify divorce.

1. The nubile age, with us, is not below fourteen for the male, and twelve for the female, that being the ordinary period of puberty in our climate; but young persons may after this age be prevented from marrying till the age of majority, by parents and guardians, in England, though this seems doubtful in Scotland.

2. The physical circumstances which may invalidate a marriage are, lunacy in either of the parties at the time, and physical inability to consummate. There are instances of this last being pleaded and sustained in our Courts. Certain diseases, such as epilepsy, are held in some countries to invalidate marriage, but not with us.

Impotence

V.—Impotence and Sterility may arise from,

1. *Functional Causes.*—Of these, habitual intoxication, excessive venery, and diseases which greatly debilitate, or affect the common sensorium, are the chief. They are generally temporary only. In females the same causes may produce sterility; to which may be added excessive leucorrhœa, dysmenorrhœa, anaphrodisia, &c.

2. *The Organic Causes* are malformation of the genitals in both sexes, or total deficiency of some of them. We must be careful, however, not to infer the want of testes,

because none are found in the scrotum. In some individuals they have remained through life in the abdomen, as occurs in the unripe fœtus.

Pregnancy.

VI.—Pregnancy presents a wide field for medico-legal evidence.

1. *The limits* between which it is possible, belong to the province of the medical jurist. It may be limited to the period during which the catamenia recur; but this varies from under ten to more than fifty years of age. A few remarkable instances of impregnation after sixty are recorded; and instances of very early puberty also have occurred, even so early as about four years; but these are exceptions to a general rule, which should be kept in mind, in judging of imputed pregnancy.

2. *The signs* of true pregnancy should be impressed on the mind of the jurist; for he may be called to determine whether a capital sentence is to be suspended on this plea, or whether an accusation of pregnancy may not, from the effect of disease, be made against a virtuous female. It is in the early months that the principal risk of error lies. The usual signs are, the cessation of the catamenia, the darkening of the areola round the nipple, the general state of the breasts, the state of the os uteri, the form of the womb as felt over the pubes; and as the pregnancy advances, the tumefaction of the abdomen, and the motions of the fœtus. At this period, the stethoscope, applied to the abdomen, affords a certain indication. The female, for this last examination, should be in bed, lying on her back, with a sheet drawn smoothly over the abdomen: place the stethoscope between the navel and the pubes, and an attentive ear will readily distinguish two sounds; a *whirring* one, synchronous with the maternal pulse; and the pulsations of the fœtal heart, considerably quicker and of a sharper tone.

3. *Limits of Utero-gestation.* Pregnancy may be protracted beyond nine months, or forty weeks, its usual term; but not so considerably as was once imagined. The Justinian and some modern codes were very indulgent in this respect. Ten kalendar months, or three hundred days, is the extreme limit allowed by the present French code; the Prussian extends it to three hundred and two days, a period sufficient to include every case of protracted pregnancy. The law of England at present has no definite limit; but a case beyond the usual term would go to a jury. The difficulty of any female ascertaining the precise period of her conception is the cause of the discrepant opinions of the physiologists on this subject.

Parturition.

VII. Parturition. This subject is also one of great delicacy, and involves several questions.

1. *Whether it be approaching* in general, may be known by indications described in all books on midwifery. The steps of natural, protracted, and preternatural labour should be familiar.

2. *But the signs of recent delivery* are more important to the jurist. These are, the bruised state of the genitals, relaxation of the vagina and of the uterus, the presence of the lochial discharge, the general appearance of the female, and the formation of milk in her breasts.

3. *The viability* of the child is very important, and is recognized by the perfection of its organs, the position of the *mesial line*, the appearance of its nails, and skin, the cry of the infant, and its capability of sucking. This is a subject of interest; because in some instances, if a child be born *not viable*, it may affect the succession to property, when the mother dies in childbed; and it may bear on certain cases of alleged infanticide. One other question connected with this subject is, when there is a considerable interval between the birth of twins, whether these are to be considered as conceived at the same time. Many deny the possibility of *superfœtation*, which in such cases is contended for by others; but it is a subject involved in much obscurity.

Monsters.

VIII. Monsters and Hermaphrodites. No living human birth, however much it differ from human shape, can be destroyed without committing a capital crime. The law states that *monsters* cannot inherit; but it has left us in the dark, as to what should be considered sufficient deviation from the human form to constitute a monster. *Hermaphrodites* are now considered as beings with malformations of the organs of either sex: and physiology does not admit the existence of true hermaphrodites with duplex perfect organs in the human species.

Paternity.

IX. Paternity and Affiliation become medico-legal questions when a considerable interval has elapsed between the birth of a child and the death or absence of its reputed father: ten kalendar months being the utmost limit to which modern physiology would extend the period of utero-gestation. This subject involves questions respecting children born during a second wedlock of the mother, the circumstances of posthumous children, the laws of bastardy, and the mode of treating alleged cases of suppositious children.

Presumptions of Survivorship.

X. Presumptions of Survivorship.

1. *When a mother and her new-born infant are found dead*, important civil rights depend on the question, which lived the longest; as the husband's right to be *tenant to the curtesy*, or the descent of property derived *from the mother*. The law of England in such cases admits such slender proofs of life in the fœtus as would not be received elsewhere, and leaves much to the evidence of a medical witness. Elsewhere the child must either cry or look around, to constitute a quick birth; but in England a quiver of the lips has been received as a proof of life, in defiance of physiology.

2. *When two or more persons perish by a common accident*, without any but probable means of ascertaining who perished first, as in cases of shipwreck, or on a field of battle, the descent of property may become the subject of dispute. Such questions have been rarely decided in Britain; but probably should be determined on the principles laid down in ancient Roman law, or in the Code-Napoleon.

Mental Alienation.

XI. Mental Alienation. This interesting subject presents a wide field for speculation to the medical jurist.

1. He should be familiar with the four forms of insanity, *Mania, Monomania, Dementia*, and *Amentia*, and be able to indicate the leading symptoms and the most judicious treatment of each. He should be able to detect feigned cases of insanity, and to prevent real lunatics from being treated as criminals.

2. *The chief questions* that may fall under his decision are, how to distinguish the disease, and to prove a man insane; if there be a real lucid interval; what period of life is most liable to insanity; what diseases are most liable to be confounded with it; whether it has increased in these kingdoms.

3. *The nature and management of Lunatic hospitals* are also in his province. It must never be forgotten, that, in such establishments, no more restraint should be employed than is necessary to prevent the unfortunate being from hurting himself or others: while the order and economy of the house is to be maintained by a mild but firm administration; rather like the authority of a parent over children, than the rigid severity of a task-master towards a dependant.

Rights of Deaf and Dumb.

XII. The Rights of the Deaf and Dumb are secured by law; and if the intellect be perfectly sound, there is now no question of their perfect competence to enjoy all the civil rights of other subjects of the state. They can intimate legal consent by signs, or by writing; and should be considered as responsible agents.

Maladies Exempting from Public Duties.

XIII. Maladies Exempting from Public Duties belong to the medical man, both in his civil and military capacity. He may be called to decide whether a man be fit, without imminent injury to his health, or danger to his life, to perform the duties of a juryman, of an officer of justice, or to serve in the navy or the army. In all such cases the certificate of health must be carefully drawn up, on an honest consideration of each case, and a fearless determination to do justice.

Simulated Diseases.

XIV. Simulated Diseases present a field of investigation, requiring caution and discrimination. It may be the duty of the medical man to aid the magistrate in the detection of the guilty impostor, or the military tribunal in consigning to merited punishment the pretended invalid. No questions require more professional skill, more self-possession, or more knowledge of human character.

SECTION II.—INJURIES TO PROPERTY.

Nuisances.

I. Nuisances from Manufactories, &c. These may affect the property of our neighbour in different ways; or the nuisance may be a public one. The first is what is termed a private nuisance, and may be abated by an action for damages; the second is a common or public nuisance, and the proper remedy is by indictment. In certain cases the injunction of a court of equity will stay the nuisance in a summary manner.

It was at one time ruled, "that usefulness shall compensate for noisesomness, and that unless it could be proved *deleterious* to the health, a manufacture, however disagreeable, might be introduced into a town:" but by several later decisions of our judges, it is sufficient to prove that the nuisance complained of is very disagreeable, and renders the property of a neighbour less valuable, or diminishes in a marked degree the comfort of his life. In judging of such cases, a medical man is often on delicate ground, between parties deeply interested in the issue of the cause: but we may in general terms conclude, that what is very disagreeable to the olfactory organs of most persons is injurious to health; and now it is sufficient to prove the very offensive nature of the nuisance, to obtain its abatement or suppression.

The principal nuisances which are likely to become the subjects of an action are:

1. Establishments or manufactures in which offensive odours are either naturally given out, or generated by *putrefaction*,—such as the erection of privies, piggeries, cattle-pens, slaughter-houses, cemeteries, collections of decaying animal and vegetable substances, steeping of hemp and flax, starch making, dealing in various animal matters, as in the trades of the *knacker* and *gut-spinner*.

2. Manufactures which evolve noxious or offensive effluvia by the *aid of heat*,—as in sugar refining, dyeing, glue-making, hartshorn and ivory-black works, Prussian blue making, rendering of fat and tallow, boiling of whale and fish oil, leaf-horn manufactories, varnish making, soap works, acid making, alkali works, preparation of chlorine, smelting houses, coal-gas works, turpentine making, unconsumed smoke from steam-boilers, &c.

3. Manufactures which *corrupt or pollute streams or springs*,—as bleaching, dyeing, tanning, gas making, lime-burning, and the like.

4. Establishments that become nuisances from their *noises*—as the business of the tin-plate worker, the copper-smith, the trunk-maker, the boiler-maker, *tilting* machinery, &c.

Arson.

II. Arson. The crime of wilful fire-raising can rarely become the subject of medico-legal investigation, except when there is a doubt whether the alleged fire may have arisen from spontaneous combustion. Spontaneous combustion may arise in inert matter from

1. *Friction or percussion*, by which the latent heat of bodies is suddenly converted into sensible heat.

2. *By fermentation* of vegetable matter,—as in the firing of new hay, of collections of linen rags, roasted bran, and powdered charcoal; in which the heat excited appears to be owing to the rapid absorption of watery vapour, which, when condensed, gives out its latent caloric in sufficient quantity to cause ignition.

3. *By chemical action*,—as in the effect of drying oils on hemp, flax, cotton, and on some powders,—as that of charcoal, and black oxide of manganese; the action of nitric acid on essential oils, indigo, &c., or the mixture of oil with wool. Under this head also may be advantageously discussed the singular combustions of the human body, which have sometimes led to accusations of murder, when the event was due to spontaneous changes in the living body.

Forgery.

III.—Forgery and Falsification of Documents.—This may be of two kinds:

1. *Forgery of Engraved or Printed Bills.*—The importance of preventing forgeries, in a great commercial country, where public and private bills form an immense portion of the circulating medium, has given rise to various contrivances for the prevention of frauds. This has been attempted by introducing peculiarities in the manufacture of the paper, as the use of *water marks*, and colouring the pulp; but ingenious knaves have imitated both successfully. It has been also attempted by employing complicated designs, not easy of imitation. The most ingenious and successful effort of this kind is the multiplication of the same design, by Mr. Perkins's machinery, through which the *same figure* cut on steel afterwards hardened, may be indefinitely multiplied, by being transferred to copper. The success of this method is proved by the very few forgeries which have taken place on the banks which have employed his plates. Substitution of one sum for another has sometimes been made. This is easiest prevented by the multiplication of the word or figures on the face of the note, and also by care in the manufacture of the printing-ink. It is found that an ink composed of lamp-black, Prussian blue or smalt, with copal varnish, is more difficult of erasure than common printer's ink.

2. *Falsification of Deeds*, and forgeries of names, have been committed by the erasure of the common ink used in the signatures. Common ink is usually effaced by diluted nitric, or oxalic acids, by solutions of chlorine, by caustic alkalis, and by butter of antimony. All these substances soften or injure the texture of the paper, but the traces of this injury have been effaced by washing, sizing, and pressing the paper. If these steps have not been carefully performed, however, the writing may, in some instances, be restored; the erasure by acids, in that case, becomes manifest on the application of an alkali—the effect of alkalis by acids; but chlorine may leave no trace of its employment, except the extreme whiteness of the paper. In deeds and writings of importance the best preventive would be to use as an ink a solution of copal in oil of lavender, coloured by lamp-black. The defect of this ink is, that it is apt to become thick; and, on this account, a solution of gluten of wheat, as the vehicle, has been proposed. (See Ink.)

Coining.

IV.—Coining of False Money.—The care with which the die is prepared will not always secure against frauds of this sort, as the coin itself offers a ready means of obtaining a mould, of sufficient sharpness for the purpose of the coiner. The object of such persons is to pass off base alloys for pieces of gold and silver. These may be detected by deficient specific gravity; but, in the ordinary business of life, this is not a practicable test. Most of the base alloys are much less sonorous than the precious metals, and the sound is therefore employed to ascertain the genuine coin. All coin is alloyed with copper, which imparts hardness, and diminishes loss in *wearing:* this quantity, in our mint, amounts to two parts of alloy for every twenty-two of pure gold or silver, or 1-12th. The simplest method of detecting the intermixture of too large a quantity of alloy is by the change of colour produced when a streak is made on *touchstone*, and compared with the streak formed by needles of metal of ascertained purity; but chemical examination is to be preferred.

1. *Debasement of Gold* is ascertained by dissolving a given weight of the alloy, cut into small pieces, in pure nitric acid. This will leave the gold, but dissolve the baser metals; and the weight of the residue, washed and dried, gives the quantity of gold present. The nature of the alloy may be found by different chemical tests. There is only one debasement of gold coin not to be thus detected. Gold coin has been debased by platinum. If the attempt be made to form an alloy, it spoils the colour of the gold; but at Rouen it was accomplished by plating the platinum with gold so nicely, as to give the piece its due weight. Cutting such a coin will detect the fraud. If an alloy has been made, it may be detected by the colour being greyish, or by dissolving the whole in nitro-muriatic acid; when the addition of muriate of potassa, or of ammonia, to the acid solution, throws down a yellow precipitate, if platinum be present.

2. *Debasement of Silver* is usually detected by *cupellation*. The weight of the button of silver left on the cupel gives the quantity of silver in the alloy. It may also be found by dissolving the alloy in nitric acid, and precipitating the solution by muriate of soda: the precipitate blackens by light, and affords the means of ascertaining the quantity of silver in the compound.

SECT. III.—INJURIES AGAINST THE PERSON.

These may be A, such as do not imply the loss of life; or B, such as usually endanger or destroy life.

A.

Defloration

I.—Defloration.—The signs of defloration are obscure. The state of the sexual organs have been chiefly relied on as indications of the loss of virginity, and in particular the rupture of the hymen; but the hymen has been found entire in some females who have had carnal intercourse with man, and is sometimes naturally wanting, or may be destroyed by disease. The appearance of the nymphæ, and the size of the vaginal orifice, are not certain indications, any more than the appearance of the carunculæ mystiformes, or the firmness of the mammæ. It is only by considering all the signs together, that we can arrive at any just conclusion.

Rape.

II.—Rape.—This crime consists in the forcible knowledge of a woman against her will; her resistance must be continued to the utmost, while she retains her senses or the power of struggling with the ravisher, unless she may have yielded to the immediate fear of death. It is not a *rape*, without these conditions being complete; the woman otherwise is supposed to have consented to the act, which may indeed have commenced in violence, but have terminated with her consent. An *infant*, however, under ten years of age, cannot give legal consent; and whoever has carnal knowledge of such an infant, either with or without her consent, is guilty of a felony. The proofs of rape, besides the consistency of the woman's story, mainly depend on the marks of violence on her person. If a virgin hath been violated, the injury to the sexual organs, with the precautions mentioned under defloration, will be taken into consideration. If a married female be the victim, we must look for bruises on her own person, or injuries she may have inflicted on the ravisher during her resistance, which last are accessory proofs of no small importance. The crime may even be perpetrated on a prostitute. It is rape, if the act be forcible, and against her will. The slightest penetration is sufficient; emission is not now required to be proved. The physical signs of rape soon pass away; and unless the female be inspected within ten days after the alleged violence, we shall, in most cases, vainly seek for confirmation of the allegation from inspection. The charge of rape is not invalidated by the female conceiving, nor by the occurrence of syphilis in the woman.

Mutilation.

III.—Mutilation.—*Demembration*, mutilation of the face, cutting or maiming, were capital crimes by Lord Ellenborough's act; but are not now capital felonies under Lord John Russell's act. The extent of the injury may often be referred to a medical man; and in a case of *slitting the nose*, an English judge overruled the objection of the prisoner's counsel, "that the nose was only *cut*," by stating, "the surgeon sware it was *slit*;" and that slit was anciently synonymous with cut. Castration was always in Britain considered as a capital offence, even when other *mayhems* (as mutilations are termed in English law) were punished by fine and imprisonment. In France, the perpetrator is condemned to hard labour for life, except where it has been "immediately provoked by an outrage against modesty." Castration, long after the infliction, may be recognised by the cicatrix of the wound.

B.

Criminal abortion.

IV.—Criminal Abortion.—The laws of Britain recognise this crime only after the period of *quickening*, on the false idea that then only life enters into the fœtus. Quickening is merely the mechanical escape of the gravid uterus from the pelvis into the abdomen, and usually takes place in the fourth month of utero-gestation. Before this has taken place, causing a woman to abort was not a crime in our code, until the act of 1st of Victoria, where no mention is made of *quickening*, which has nothing to do with the life of the fœtus: and the penalty for causing abortion is transportation for a period not less than fifteen years. The chief means by which abortion is sought to be accomplished are, by blows and bruises on the abdomen, by the administration of drastic purgatives, or other medicines acting violently on the human frame, by repeated venesection, and by the introduction of pointed instruments into the womb. None of the means, except the last, are certain in their operation, but all are highly dangerous to the mother; and one who only essays abortion may thus commit a double murder. In cases of alleged abortion, the medical witness has to consider the involuntary causes which may produce it; as accidental falls and blows, strong mental emotions, errors of diet and regimen, or spasmodic diseases; and he should balance these against the marks of premeditated design.

Infanticide.

V.—Infanticide.—By the laws of Britain, the mother who concealed her pregnancy till she was delivered of a dead child, or who, during labour, failed to cry out for assistance, or whose infant disappeared after birth, was formerly held guilty of infanticide; and many convictions and executions took place on this cruel statute. In later times very moderate proof of these three circumstances was held sufficient to invalidate the capital charge. Even in England, in cases of the murder of bastard children, contrary to all the usual forms of justice, a statute of James I. threw the *onus* of proving her innocence on the mother; and it was not until the 43d year of George III. that this iniquitous law was repealed, and the same rules of evidence here applied as in other cases of murder.

This subject involves some very nice points of legal medicine. The proofs of the child being born alive enter into the case. It must be proved to have arrived at the period when there was a probability of its living; its body should be carefully inspected for marks of wounds or bruises; its cavities should be opened, lest there be traces of injuries sufficient to have caused death, found in the head, abdomen, or chest; the state of the peculiarities in the fœtal circulation, and of the organs of respiration, must be examined; and we must observe whether the lungs seem to have been dilated by breathing, or remain in the dense condition and backward position they have before respiration has commenced. This leads us to consider the celebrated *docimasia pulmonum*, or test by their sinking or floating in water, which was at one time regarded as indisputable proof of the death of the child, before or after birth, but has now been considered as ambiguous. If, however, we try the lungs together with the heart, with that organ separated, each lung separately, and also detached portions of the lungs, we shall generally find little difficulty in deciding the important question, especially if attention be paid to the quantity of blood in the lungs, and the state of the *ductus venosus* and *d. arteriosus*, the contents of the air-tubes, and of the alimentary canal. We must carefully distinguish between the effects of artificial insufflation of the lungs after death, and their floating from respiration, or from incipient putrefaction. In cases of artificial insufflation, the whole lungs will not float, and the air may be squeezed out of a cut portion of the lungs, so as to sink in water; whereas, it is not possible, by compression with the thumb and finger, so to free from air a portion of lung that has respired, that it will not float. Putrefaction may be distinguished by the smell, and the air not being in the cells, but in oblong globules in the cellular tissue uniting the cells.

Infanticide from strangulation, from drowning, and from mephitic air, may be distinguished by the marks to be mentioned under *asphyxia*. Infanticide may be produced by *omission*, as by neglecting to tie the navel string; in which case the body will appear bloodless, the great vessels near the heart, and that organ itself will be empty. The child may perish, if not removed from the discharges which accompany delivery; and the possibility of this happening, without any fault of the mother, must be taken into consideration. The infant may die from exposure to cold. If it be found in a remote or sequestered situation, that would be ground for suspicion. If there be meconium discharged from its bowels; if it exhibit marks of starvation, in the emptiness of its alimentary canal; or if it appear to have been fed, we may be sure that it was born alive, and probably perished from criminal neglect. Any artificial objects, such as articles of dress, found near the child, should be carefully preserved, as one means of identifying the exposer; and if foot-marks are seen there, they should be accurately measured and noted.

In cases of exposed infants, it is very important to ascertain the real mother. As such exposure usually takes place soon after birth, comparing the age of the infant with the signs of recent delivery on the suspected mother, is the best method of proving the connection between them.

Homicide.

VI.—Homicide.—It is only with culpable homicide, and with murder, that the medical jurist has to deal. When a person is found apparently dead, a medical man may be required to inspect and report on the cause of death. He should, of course, first ascertain whether it be a case of real or only of apparent death. This sometimes is not easy. Singular instances of resuscitation from apparent death are noticed by Winslow, Bruhier, and others, which should make us pause ere we hastily pronounce a person dead, without evident causes for his death appearing on his body. Neither pallor of the face and lips, insensibility to stimuli, cessation of the organs of respiration and circulation, loss of heat, nor even stiffness of the limbs, are infallible criteria. Until, along with these, we have marks of incipient putrefaction or decomposition, we cannot be absolutely certain that a person is quite dead; and, in all cases of doubt, we should wait for incipient putrefaction ere we sanction interment. Where the symptoms appear at all equivocal, we should scarify, or apply hot oil to some parts of the skin.

Here it may be proper to describe the general method of carrying on the *medico-legal* examination of a body.

In cases where a person is found dead, the body should be carefully inspected for external wounds or marks of contusions. Any wound, however minute, should be traced with a probe, and followed to its termination by the knife. Blackish marks should be cut into, in order to ascertain whether they be the effect of the effusion of coagulated blood, or merely the consequences of that infiltration of the skin which takes place in the depending parts of bodies after death. The first is termed *ecchymosis;* the latter may be distinguished from the former by the name of *sugillation.* In the subsequent examination of the head, the hair should be removed, the scalp inspected, and afterwards divided from ear to ear, over the vertex; the skull-cap removed; the state of the brain and its membranes carefully marked, and especially any unusual appearances noted down. All should, on the spot, be committed to writing —nothing trusted to the memory, however tenacious. The inspection of the larynx, trachea, and gullet, is best performed by making a cut through the lower lip, and down the fore part of the neck and chest, to the xiphoid cartilage. Transverse cuts should then be extended from the longitudinal one, along the edges of the lower jaw and the collar bones, so as to enable us to turn back the integuments of the neck. The symphysis of the chin should then be sawed through, and the soft parts divided. We can thus separate the two sides of the lower jaw. When the tongue is pulled forward, the fauces, and upper part of the œsophagus and larynx, are freely exposed, and the introduction of acrid poisons, or of foreign bodies, may often be thus detected. The state of the cartilages of the larynx and trachea should be noted, as fracture or displacement of these has occasionally detected strangulation. A ligature should be put on the lower part of the gullet, and the tube divided above the ligature.

The abdomen may next be opened, by a cut through the skin from the sternum to the pubes. In new-born infants the whole skin and abdominal muscles may at once be cut through, along the cartilages of the ribs on each side, and thence to the anterior edge of the ileum, curving downward to the pubes. This will, when the flap thus formed is turned down, expose the abdominal viscera sufficiently, without disturbing the vessels of the umbilical cord. In the adult, we may first separate the skin of the abdomen from the muscles, in one line from the sternum to the pubes, and, as it is easily extensile, cut out a flap of the muscles of the abdomen, as above directed, so as to expose the viscera. The skin so divided makes a neater appearance when sewed up, than when the muscles and skin are divided together, as in the infant. A ligature should be put on the duodenum, and division of the intestines made below the ligature; so that we may remove the stomach and its contents, and reserve them for subsequent examination. The other viscera should also be carefully inspected. The thorax should be last examined; because this enables us the better to ascertain the descent of the diaphragm, and the arching of the chest, which takes place in asphyxia, than when we open the chest before the abdomen. The cartilages of the ribs should be divided as close as possible to the ends of the ribs, as thus a larger opening is made in the chest. The position and appearance of the lungs and heart should be noted, and their engorgement with blood, or the emptiness of the great vessels, ascertained. When it is necessary to examine the spinal canal, the body must be laid on a table with the face downwards: an incision is to be made along the whole spine, from the occiput to the sacrum, the integuments are to be separated on each side, so as to expose the posterior portion of the vertebræ, which may be divided near the transverse processes by a saw, the *rachitome*, or by cutting plyers. A triangular piece should also be sawed out of the occipital bone at the foramen magnum. This will expose the whole spinal canal.

Homicide may be accomplished by several modes that may sometimes be ascertained by examination of the body.

Death from Suffocation

Death by *Asphyxia* or suffocation may be produced by drowning, by hanging, by strangulation, and by mephitic air.

1. *Drowning* may produce the fatal effect in two different modes. In some the suddenness of the shock, or the surprise instantaneously arrests both the functions of circulation and of respiration; no struggle precedes death. This species of drowning has been justly compared to syncope; and hence has been by Desgranges termed *asphyxia syncopalis.* In others the circulation goes on for some time after the respiration has been interrupted; the animal struggles, makes vain efforts at inspiration, and portions of air are forced out of the lungs by a convulsive effort of the muscles of respiration. The circulation of unoxygenated blood through the brain seems to act as poison on that delicate organ; and the consequence is diminution of nervous energy over all the body, by which the play of the heart is enfeebled and the animal soon dies. In this case the brain is usually found congested with dark blood. This state has been aptly termed *aphyxia congestiva.* This difference in the phenomena may account for the great difference perceived in the bodies of drowned persons, and also for the difference in the chances of recovery after submersion. In the first species the pallor of the countenance is marked, and the features little altered. In the latter, the face will often appear swelled and livid, the tongue be protruded, the nose and air passages filled with frothy mucous, the brain and right side of the heart gorged with black blood. The body which has been sometime immersed is generally pale, the eyes are half open, and the pupils generally much dilated, the chest arched, and the diaphragm pushed down into the abdomen. These last signs are most conspicuous in those who have perished from *asphyxia congestiva.* When the person has retained his sensibility after falling into the water, the ends of the fingers are often found excoriated by his grasping at any object within his reach; and mud or gravel will often be found lodged below his nails. The blood in drowned persons generally remains fluid. These are the principal signs by which we can distinguish the extinction of life by drowning, from the cases in which the person has been thrown into the water after death. If we find in the stomach water containing any foreign bodies, such as fragments of straws or weeds, similar to those in the water in which the body was found, we may be sure that the person was living when immersed in the water: for no water will enter the stomach after death.

It may, however, be very difficult to distinguish a murder by drowning, from death by accidentally falling into water, or from a suicide. The most material circumstances will be, the marks of struggle near the spot where the body has been immersed, the obstacles in the way, the impressions of the feet of more than one person leading to the water. We must also pay attention to appearances of injuries on the body, which could not have occurred from simply falling into the water; such as marks of strangulation on the neck, or wounds inflicted by deadly instruments.

2. *Hanging* produces most of the internal appearances just described; such as turgescence of the vessels of the head, livor of the face, fluid black blood in the lungs and right side of the heart, protrusion of the tongue, and the nose loaded with mucus: but besides these, we usually find a mark round the neck; and when the person has undergone a public execution, especially when the *drop* is employed, there is often luxation of the neck, and fracture of the *processus dentatus.* Ecchymosis is generally found under the mark of the rope: sometimes this mark is not apparent until some hours after death, but dissection will shew the cellular tissue, beneath the rope, dry and compressed. The face is generally less distorted, the eyes less prominent, in those in whom luxation of the neck is produced by the drop, than when the struggle is more protracted. Recovery is hopeless in the first case, but has sometimes followed the asphyxia produced by mere strangulation, which seems to cause a stupor, that is, however, soon fatal, if the person be not soon relieved.

In examining the body of a person found suspended by the neck, we must determine whether this be really the mode in which life was extinguished, or whether the body was suspended after death. The absence of the usual marks of hanging, the position of the rope-mark on the neck, the presence of other mortal injuries, the appearance of the rope are all important objects of consideration. These become of the utmost importance in the difficult cases, where there is a doubt whether the person was murdered or committed suicide. We must rely for a solution of the problem on the indications just noticed, and the previous history of the individual.

3. *Strangling* may be accomplished by drawing a rope tightly round the neck, or by forcibly compressing the anterior of the windpipe, after the manner of Burke and his imitators. In the first, the mark round the neck will generally be nearly circular and not inclined to the ear or occiput. In the latter, marks of fingers will often be perceived on the neck, or a circular depression will be found on the front of the windpipe, and sometimes some of its cartilaginous rings will be broken or displaced. The signs of suffocation will be equally present, as in hanging; but if the mark of the cord be on the *lower* part of the neck, it cannot be a case of death by hanging.

Suffocation has sometimes occured from bulky substances sticking in the gullet, and compressing the trachea. Assassination has also been effected on infants, or on feeble individuals, by covering up the mouth and nose. This last mode leaves no external marks of violence, and can scarcely be detected, except by the appearances of suffocation found after death.

4. *Mephitism*, or death from irrespirable gases, often happens accidentally, but is seldom the mode of assassinaation, except in cases of infanticide: and will be noticed under Toxicology.

In every case of suffocation our attempts at reanimation should be directed to renew respiration by inflation of the lungs, to restore the animal heat by exposure to warm pure air, and by assiduous frictions of the surface, to rouse by stimuli, and by brushing the soles of the feet and palms of the hands, to relieve cerebral congestion, when necessary, by moderate and cautious bleeding.

Death from Starvation.

VII. Death from Starvation. Cases may occur where it is important to distinguish this from other modes of the extinction of life. In such cases the cutaneous veins disappear, the skin has become harsh and has a shrivelled look; the fat has disappeared, and the soft parts are mostly wasted; the gums desert the teeth; the eyes are commonly more or less open and bloodshot; the tongue and fauces are dark and dry; the stomach shrunk, blackish and ulcerated on its internal surface; the intestines resemble a cord; the gall bladder is gorged with bile, which stains the intestines to a considerable extent; the heart is wasted, and the great vessels are almost empty; the body exhales a most offensive odour of putridity, even before life is extinct.

The period required to destroy life in inanition is very various, and appears to be shorter in the young and vigorous than in persons of middle life, in men than in women. In some comatose diseases, and in persons reduced by previous illness, the life under inanition has occasionally been greatly protracted; and when there has been stupor with occasional intermissions, an astonishingly small quantity of liquid aliment has prolonged life for many weeks, months, or even years. Some of the published cases of *fasting* are apocryphal; but in others where the quantity of nutriment has been extremely small, the individuals may be considered as in the state of hybernating animals, where the diminished nervous energy renders the waste of the system exceedingly slow. Those who are deprived also of drink perish soonest of inanition; and those who are confined in dry warm air, than those exposed to a moist, cool atmosphere.

Death from extremes of Temperature.

VIII. Death from Extremes of Temperature.

1. *From extremes of cold.* After the sensation of tingling in the fingers and toes, exposure to extreme cold is soon followed by languor, loss of sensation, and irresistible propensity to sleep, which is so oppressive, that even the known fatality of the indulgence while exposed to the cold is insufficient to prevent the sufferer to seek repose. Cold does not seem to produce a painful death. In arctic regions the best preservatives against extreme cold are, woollen garments next the skin, with furs and dressed leather over them, a free use of warm diluents, and avoiding wine and spirits.

2. *From a much increased temperature*, the fatal effects may be *scalding* or *burning*, according to the medium applied. This mode of extinction of life leaves very obvious traces on the body. Sometimes fire has been applied to the body after death, to conceal a murder. This fact suggests the propriety of the medical man examining a scorched body minutely, lest there be wounds on its surface, inflicted during life. If the person has lived sometime after the scorching, in general there will be found a ring of inflammation surrounding the eschars: but this only takes place when the burning has not been so severe as to sink the powers of life beyond the capability of reaction.

An increased temperature may be insufficient to vesicate or destroy the skin, yet may prove fatal; as is well known in what is termed a *coup de soleil.* This is a species of apoplexy, chiefly induced by the direct influence of the sun on the head, and appears to be similar to the effect of the *Khamsin* or *Simoon* of the desert.

3. *Death from lightning* is not wholly to be attributed to the high temperature, but partly to the impulse or shock instantly affecting the brain, and paralyzing the heart: yet as the marks of singeing are often observed on the bodies of those killed by lightning, it may be here considered. The skin is sometimes discoloured in stripes or oblong patches; at other times the surface has no mark of injury, but the viscera have been observed more or less affected, and occasionally there is a small perforation on the skin. The blood is described in every case as remaining fluid, and the corpse runs rapidly to putrefaction.

Wounds.

IX. Wounds. The examination of wounds, whether fatal or not, often becomes an important branch of legal medicine. Wounds are usually divided into contusions, lacerations, incisions, stabs, gunshot and poisoned wounds. Each kind requires to be minutely examined, and described, as they are in approved works on surgery. The degree of danger from each should be familiar to the jurist; and he should recollect that there is scarcely any wound which may not become *incidentally* fatal from improper treatment, or peculiarities in constitution. Punctured wounds or stabs require minute attention; for there have been instances in which death has been produced by an instrument not thicker than a pin, thrust into the brain, the spinal marrow, or the heart.

Poisoned wounds belong to Toxicology.

Wounds are more or less dangerous according to their locality.

1. *Wounds of the head* are always dangerous, especially if the blow has been considerable. The person so wounded may die without separation of the integuments or fracture of the bone; as happens in what is termed *concussion* of the brain. Contusions which do not divide the skin may fracture the skull; or the inner table of the skull may be fractured without the outer being broken or depressed. Even wounds of the integuments may prove fatal, from inflammation extending inwards to the brain. Punctured wounds of the head are more dangerous than cuts, as more likely to excite fatal inflammation. When the brain or its meninges are injured, all such wounds are generally fatal.

Wounds of the face or organs of sense are often dangerous, and always disfiguring. Malicious disfiguring of the face was made a capital felony in the reign of Charles II., by the *Coventry act;* but the monstrous anomaly pointed out by Filangieri, that disfiguring *with the intent to disfigure* was punished with death, while *the intent to murder* was not capital, no longer disgraces our statute book. Wounds of any of the organs of sense are generally dangerous, and always produce serious inconvenience.

2. *Wounds of the neck* are always very serious wherever more than the integument is divided. The danger of opening large blood-vessels, or injuring important nerves, is imminent: even the division of a considerable vein in the neck has proved immediately fatal, from the entrance of air into the vessel, and its speedy conveyance to the heart. A blow on the side of the neck has instantly proved fatal, either from the blood being forced back into the brain, or from injury to the superior parts of the par vagum, the great sympathetic, or the other cervical nerves. Dislocations and fractures of the bones of the neck prove instantly fatal.

3. *Wounds of the Chest* are always serious, when the cavity is penetrated, though persons have recovered from wounds of the lungs, and have even survived for some time considerable wounds of the heart. This last is an important fact; because we are not always to consider the spot where the body of a person killed by a wound of the heart, and apparently remaining where he fell, is found, as that in which the death-wound was inflicted. Instances have occurred of persons surviving severe wounds of the heart for several days. Fractured ribs are never without danger; and the same may be said of severe contusions of the chest, from the chance of inflammation extending inwards. Wounds penetrating both sides of the chest are generally considered as fatal, though animals have recovered after having both sides of the thorax penetrated, and the wounds kept open for some minutes.

4. *Wounds of the Abdomen*, when they do not completely penetrate, may be considered as simple wounds, unless when inflicted with great force, so as to bruise the contents of the cavity; in that case, they may produce death without breach of surface, as sometimes happens from blows or kicks on the belly. Wounds injuring the general peritonæum, or that duplicature of it investing the stomach and intestines, are highly perilous, from the risk of severe inflammation. Wounds of the stomach or intestines, or of the gall bladder, generally prove mortal, from the effusion of their contents into the general cavity producing fatal inflammation. Wounds of the liver, spleen, or kidneys, are generally soon mortal, from the great vascularity of those organs.

5. *Wounds of the Extremities*, when fatal, may generally be considered so from excessive hæmorrhage, from the consequences of inflammation and gangrene, or from the shock to the system, when large portions of the limb are forcibly removed, as in accidents from machinery, and in wounds from fire-arms.

X.—Toxicology.—This most important branch of legal medicine has been more thoroughly investigated than any other part of Medical Jurisprudence. A poison may be defined *a substance capable of impairing or extinguishing the vital functions, in a great majority of cases.* This limitation is necessary, because some of the most deadly substances, in small doses, may be taken not only with impunity, but with salutary effects; and habit renders doses of them innocuous, which would destroy an individual unaccustomed to their use. Some poisons act directly on the organs to which they are applied; others appear to act by their influence on the nervous system. Some appear to act merely as irritants or escharotics; others by directly impairing vital functions; and some have a twofold action. The manner in which poisons affect the system appears to be either through their direct influence on the extremities of the nerves to which they are applied, or by absorption, and consequently by the circulating fluids. The rapidity with which some poisons, as hydrocyanic acid, act, favours the opinion that their influence is instantaneously conveyed to the vital organs by nervous communication. The detection of poisons, in some instances, in the blood, or in the exhalations or secretions, favours the opinion of the circulation being one channel by which they are carried to the system; a fact which is further confirmed, by the effect of ligature, or of division of vessels, in preventing the constitutional affection of the poison on the system. Some poisons exert their deleterious influence on one organ, or set of organs; others generally affect the system. Poisons, classed according to their effects, may be divided into *irritants, narcotics, narcotico-acrids*, and *septics*. Their action is modified by the tissue to which they are applied, the constitution of the individual, the quantity of the poison, and its mechanical state.

The mode of treatment of poisoned persons depends on the nature of the poison. The first indication is undoubtedly to evacuate the poison as speedily as possible, by the stomach-pump or by emetics; the second, to administer antidotes, if any such be known for the particular poison; the third, to shield the stomach and *primæ viæ* against the acrimony of the substance; and, lastly, to obviate any violent or untoward symptoms they may produce, by all the resources of our art.

The evidence of poisoning may be presumptive, or positive, physical, or moral. The physical proofs are derived from the symptoms, from experiments on the lower animals, and from a chemical investigation of the *ingesta* or *egesta*. The symptoms, however, only supply us with probable evidence; but the most important inferences they afford are deduced from the simultaneous occurrence of similar symptoms, in more than one individual previously in good health, soon after a meal on the same articles of diet. Experiments on the lower animals with the remains of the ingesta, or portions of egesta, are not much to be relied on, as all animals are not equally susceptible of the same poisons; and what is deleterious to one is innocuous to another. Some poisons, however, such as arsenic and corrosive sublimate, are equally poisonous to all. Such experiments we consider as scarcely justifiable, except in the cases of some vegetable poisons, which cannot otherwise be readily detected. The evidence from chemical analysis of the stomach, of the ingesta or of the egesta, is the most unexceptionable. The refinements of modern chemistry have enabled us to detect surprisingly minute quantities of inorganic poisons, and even of some vegetable poisons. In such investigations, the contents of the stomach, or egesta, should be put into clean vessels; if too thick, diluted with distilled water, boiled, and when cold, filtered through muslin, and then through paper. If the filtered liquor contain much animal matter, this must be separated, as it obscures the various tests to be applied. This in general is best done by acidulating the liquor with vinegar, by again boiling and filtering. Sometimes it requires to be further clarified, by the addition of animal charcoal, or of nitrate of silver, which separate all the animal or vegetable matter. To portions of the clear and colourless liquid thus obtained various tests are applied, the effects of which will decide the nature of the poison. Sometimes the whole poison may have been so evacuated by vomiting, or taken up by absorption, that not a trace remains in the contents of the stomach. In this case we can occasionally detect it, by cutting the stomach into pieces, boiling them in distilled water, purifying the liquid by some of the processes already described, and then applying the tests. Narcotic poisons are easiest detected by their smell; sometimes we can eliminate one or more of their peculiar ingredients by chemical means, but frequently we have no better means of detecting them than by the symptoms they produce, and the moral evidence of the case, or the morbid appearances on the body after death.

We are not to regard the livid appearance of the body as evidence of poisoning; it is not always present in cases of poisoning, and may arise from other causes. The rapid putrefaction of the body is as fallacious an indication. The very reverse is sometimes the fact. The classes of irritant and narcotico-acrid poisons are usually indicated by inflammatory appearances in the primæ viæ, but these are not invariably present; and cases often occur of which the moral evidence may be strong, yet the direct evidence may amount to no more than a probability.

The moral evidence of poisoning may sometimes be best collected by the medical attendant. He may be the only witness to the conduct of the accused; he may have observed him suspiciously active in removing every trace of the potion administered, or of the egesta in which a poison might be detected; he may have observed the guilty confusion of the suspected person, or heard his attempts to explain a fatal mistake, if the administration has been traced to him; or the physician may have been the chief depositary of the dying declaration of the sufferer. All these things it is his duty to note down, and to transmit to the proper authorities.

Poisons are derived from the inorganic or organic kingdoms of nature. The first class may be metallic, earthy, alkaline, and simple chemical substances, and gaseous bodies: the second vegetable and animal poisons.

Metallic Poisons.

i.—Metallic Poisons.—Of these arsenic, quicksilver, copper, lead, antimony, zinc, tin, bismuth, chrome, silver, gold, are the most important.

1. *Arsenic* is poisonous in all its combinations. Its most usual preparations given as poisons are, the blackish oxide or fly powder, the white oxide or arsenious acid, the sulphurets, and the combination of arsenious and arsenic acids with alkalis. All are very deadly, even in small doses, whether swallowed, introduced into the anus or the vagina, applied to the abraded surface, or even when extensively applied to the whole skin. The symptoms commence usually within an hour after the administration; and are, nausea, vomiting, great heat and pain in the stomach, purging, intense thirst, severe spasms in the limbs and body, prostration of strength, pallor of the face, a feeble pulse; sometimes convulsions precede death. In a few cases the symptoms of an irritant poison are wanting, and the arsenic appears to be fatal by immediately inducing paralysis of the heart.

The fauces, gullet, and stomach are often found marked by inflamed patches of a deep vinaceous colour, produced by blood effused under the villous coat of the stomach. Sometimes the villous coat appears corroded or thickened, but the stomach is seldom perforated. When the villous coat has suffered erosion, the poison has generally been given in the solid form, and grains of it may often be picked off the surface of the stomach for analysis. The inflammation seldom reaches to the jejunum; but, though the greatest portion of the small intestines and the colon escape, marks of irritation are often observed about the rectum, especially if the purging has been violent. Various antidotes have been proposed, such as charcoal and magnesia; but the only substance that seems to deserve any reputation is the recently prepared *hydrated peroxide of iron*, promptly administered in large doses.

The means of detection, when the arsenic is solid, are easy. Introducing it, with charcoal powder if it be white arsenic, or with black flux if it be orpiment, into a small tube, and applying gradually the heat of a spirit lamp, will afford a blackish, shining, metallic crust, the interior of which is crystalline. A portion of this, exposed to heat, exhales as a white smoke, and gives out an alliaceous odour. Another portion, slowly heated in a tube open at both ends, is converted into minute tetrahedral crystals. When it exists in solution in the contents of the stomach, we have to clarify the liquid, by the means already mentioned, and to apply tests; of which the most approved is a stream of sulphuretted hydrogen, which throws down a lively yellow precipitate; the ammoniaco-nitrate of silver, which gives a yellow precipitate, that soon fades to a brown; ammoniaco-sulphate of copper, which gives a green precipitate. Either of these precipitates heated with black or soda flux, in a glass tube, will afford the crust already described. These indications leave no doubt of the presence of arsenic; and from the $\frac{1}{200}$ or $\frac{1}{300}$ of a grain may be converted into a sensible metallic crust. Arsenic seems to have a tendency to preserve from putrefaction the stomachs of persons poisoned by it; and it has been detected in bodies that have been from four months to two years buried.

2. *Mercury or Quicksilver.*—This metal in its pure state has been supposed innocent; but when in the state of vapour it is well known to be speedily deleterious, and to produce all the symptoms of mercurial poison. The most usual mercurial poisons are corrosive sublimate, or bichloride of mercury, its oxides, and sub-salts. The long-continued use of calomel is capable also of acting as a poison; but almost the only mercurial poison criminally administered is corrosive sublimate, though, from its detestable taste, it cannot be given by the mouth as a secret poison.

The usual indications are a styptic taste, then burning of the throat, violent vomiting, great distress in the stomach and bowels, violent cholic and severe purging, blood mingled with the matter brought up by vomiting, or ejected by stool. The symptoms often simulate dysentery: the face at first is often flushed, the eyes sparkling; soon the powers of life sink, the voice is lost, cold clammy sweats bedew the surface, perception of external objects is lost, and convulsions close the scene. When the substance is given in small doses, or if the mercurial be a milder preparation, after dysenteric symptoms ptyalism supervenes; the person may sink from the violence of that affection, the fauces may become ulcerated, and gangrene may ensue. If ptyalism follow the administration of a single large dose of mercurial, it is always to be regarded as a formidable symptom. When the person survives, he may suffer from mercurial palsy.

The effects of mercurial poisons are indicated after death by the following appearances. The fauces are generally more affected than from arsenic, and the inflammatory appearances are more diffused over the alimentary canal. Destruction of the coats of the stomach are often observed, either the consequence of the escharotic power of corrosive sublimate, or of ulceration. Peritonæal inflammation is not uncommon; and irritation of the urinary organs, perceived during life, is marked by inflammatory indications found after death.

We possess in whites of eggs, milk, and gluten of wheat, very effectual antidotes for the poison of corrosive sublimate, provided they be given soon after the poison. The first is the most powerful. The secondary symptoms must be met by antiphlogistic remedies and venesection.

Mercurial poisons are easily detected when we obtain them in substance, but not so readily when mingled with the contents of the stomach. Corrosive sublimate is readily decomposed by several animal substances, and therefore we are not likely to detect it unchanged in the contents of the stomach. It is there usually converted into calomel, either in whole or in part. When held in solution, it is easily detected by Sylvester's method, *i.e.* by dropping a little of the suspected liquid, slightly acidulated, on a gold plate, or a gilt card, and touching the gold surface, through the liquid, with a piece of zinc or iron wire. Professor Traill employs a similar method to separate the whole mercury from its solution. He wraps a gold leaf round a slip of zinc, and immerses it in the suspected liquor, slightly acidulated—the mercury is precipitated; and scraping off the gold and the tarnished surface of the zinc, he introduces them into a small tube, and the heat of a spirit lamp is sufficient to produce a ring of brilliant metallic globules. He has employed a similar method to separate arsenic from its solutions.

In all probability the mercurial will not be found in the stomach in a soluble state. In this case we have to form the contents of the stomach into a pulp, and to pass a stream of chlorine through the mass, when the mercurial present will be converted into bichloride, which may be separated by filtration; drive off the excess of chlorine by boiling the liquid, and then either precipitate the mercury, by introducing into the liquid a cylinder of pure tin, according to Devergie's method, or by Traill's combination of zinc and gold leaf. The tarnished surface of the metals in either case is to be scraped, and the powder so obtained introduced into the tube and heated, as already described.*

When we have much corrosive sublimate to operate on, we may try it by lime water, which throws it down of a deep yellow; by alkalis, which form with it an orange precipitate; by protomuriate of tin, which gives a slate-grey powder; and by hydriodate of potassa, which forms a splendid scarlet precipitate.

3. *Copper.*—The poisonous effects of the salts of copper have long been known; but though little likely to be used as secret poisons, they sometimes produce death from being accidentally mingled with food, as in the use of culinary utensils of copper. The symptoms are those of other irritant poisons, to which is added spasmodic rigidity of the limbs, in some cases amounting almost to tetanus. Salts of copper may produce salivation, and also jaundice. The morbid appearances are not very characteristic.

Albumen of eggs appears an antidote of some power against the salts of copper, and therefore, after evacuating the stomach, the whites of raw eggs should be administered. Inflammation should be obviated by antiphlogistic means.

The poison of copper may be sought for by boiling the contents of the stomach with acetic acid; this will dissolve every preparation of copper, and enable us to separate them from animal and vegetable matter by the filter. We may, if necessary, concentrate the solution by evaporation; and if the addition of ammonia give the solution a blue colour, we may be satisfied that it contains copper. A stream of sulphuretted hydrogen throws down a brown precipitate from the solution of copper; and if the quantity of copper be considerable, a piece of bright polished iron will become coated with a film of copper.

4. *Lead.*—The poison of lead is of considerable consequence, although never used as a secret instrument of revenge. Its oxides and salts all appear to be deleterious, but those from which accidents have most commonly happened are litharge, white lead, and sugar of lead. These

often find their way into the stomach, from little-suspected sources, and produce a species of poisoning with very peculiar symptoms. Leaden pipes and cisterns are acted on by water, especially by soft rain-water, and the carbonate of lead thus formed being soluble in an excess of carbonic acid, is liable to enter the human system with the food. Acescent articles of diet act on leaden vessels, and, when aided by heat, on the plumbiferous glazes of our earthenware. These are the most general sources of this poison; but persons engaged in works where white lead is largely used, smelters of lead ores, painters, and potters, are liable to the same deleterious influence. The symptoms produced are obstinate constipation, severe tormina, with the symptoms commonly known by the name of *painter's colic, colic of Poitou*, and of *Devonshire*. After these have subsisted for some time, the person begins to have paralysis of the limbs, first of one or both arms; in general the extensor muscles suffer before the flexors, and the palsy may then become general in that limb, or extend to other parts. The preparations of lead, when given in large doses, appear to act as irritant poisons.

Orfila found that animals poisoned by sugar of lead had a preternatural whiteness of the villous coat of the stomach, if they perished speedily; but, if their death were protracted, the inner coat of the stomach was reddened. The stomach has often been found corrugated after death.

Frequent ablution of the surface is the best prophylactic for those much exposed to the powder of the preparations of lead; and when lead has been introduced into the system with the food, the best means of obviating the return of the evil is by rigidly excluding lead from all culinary and economic purposes. Hard water is less liable to act on lead than soft water, and hence the impropriety of lead cisterns for rain water. Mercury seems to have a beneficial effect in lead colic, especially when conjoined with opium.

Lead is easily detected. To whatever articles it is suspected to enter add vinegar, and boil; filter the solution and all the lead will be in the clear liquor. If in large quantity, it may be detected by the sweetish astringent taste of the liquid; part of which may be tried by the addition of a solution of sulphuretted hydrogen, or of hydrosulphuret of ammonia, which instantly darkens the most dilute solution of lead; another portion may be tried by bichromate of potassa, which throws down solutions of lead of a brilliant yellow; a similar colour is formed with them and hydriodate of potassa.

5. *Antimony* is rarely a poison; because its most active and best known preparations are violently emetic, and thus counteract its effects. Emetic tartar, when given to the lower animals, if vomiting be prevented by tying the gullet, causes inflammation of the lungs and stomach; and this would probably be its effects on man. The lungs appeared a mixture of orange-red, and violet-blue, and they were gorged with blood, which prevented the usual crepitus. It was also fatal when applied to a wound. The stomach was violet coloured, thickened, and covered with tough mucus, the intestines empty, in a man killed by emetic tartar.

The best antidote for this poison is decoction of peruvian bark, especially of *cinchona cordifolia*.

The detection is not difficult: sulphuretted hydrogen throws down a rich orange-red precipitate. When the antimony is mixed with animal and vegetable matter, add first a little muriatic acid to precipitate the contaminating substances, and then tartaric acid to dissolve any antimonial present. This will afford by filtration a clear liquid for the application of the tests. The sulphuret is best reduced by Dr. Turner's process; *i. e.* passing a stream of hydrogen over it when heated to redness in a tube.

6. *The other metals*, though affording some poisonous salts, scarcely require notice in this place. *Zinc* in solution may be detected by a stream of sulphureted hydrogen affording a whitish precipitate. *The muriate of tin* affords one of a rich purple, the powder of Cassius, with deuto-muriate of gold; and when strong, coagulates milk completely. *Sub-nitrate of bismuth* may be detected by calcining in a moderate heat the contents of the stomach, and adding diluted nitric acid to form a solution, from which water throws down a white precipitate. The soluble *salts of silver* are thrown down by alkaline and earthy muriates; and the precipitate is easily fusible into *horn-silver*. A plate of copper becomes silvered by immersion in the solution of silver. *Gold* may be detected by solution in nitro-muriatic acid; which solution affords the purple powder of Cassius with muriate of tin; and the neutral solutions of gold instantly gild silver or copper immersed in them.

Earthy and Alkaline Poisons.

II. EARTHY AND ALKALINE POISONS.

1. *Baryta.*—Both the carbonate and pure baryta are very poisonous, as are the soluble salts of this earth. The symptoms are those of irritant poisons: the senses then become blunted, the respiration feeble, and convulsions close the scene. The stomach is found inflamed, and the brain shews congestive apoplexy. The antidotes are any of the alkaline sulphates, which instantly form with all the poisonous salts of baryta, insoluble, inert compounds. Sulphuric acid, or sulphates, are also the tests of this earth: but it might be confounded with strontia, the salts of which do not seem poisonous, except in as far as they are acrid. The best distinction is obtained by procuring a muriate of the suspected salt, and dissolving it in alcohol. The muriate of baryta imparts a yellow colour to the flame of spirit; the muriate of strontia, a fine red.

2. *Lime* is only poisonous as an acrid. The antidotes for it are phosphates of soda or potassa, and water impregnated with carbonic acid. The detection of the salts of lime is easy. Its properties when pure are alkaline: it forms with sulphuric acid a substance of little solubility; but phosphoric and oxalic acids precipitate it from all its soluble combinations.

3. *Potassa* and *Soda.*—The pure alkalis and their carbonates are poisonous. Several fatal accidents have happened from them. They act as strong irritant poisons, producing intense heat and pain in the abdomen, then cold sweats, tremors, and convulsive twitchings in the limbs, the stools are tinged with blood, and membranous flakes are mixed with the egesta. When the person lives some time, general peritoneal inflammation is observed after death. Nitrate, and chlorate of potassa are irritant poisons in large doses, producing dangerous inflammation of the stomach and bowels.

The best remedies are large quantities of mild oil. The tests of the alkalis are obtained from their combinations with different acids, and the manner in which they colour the flame of the blowpipe. When nitrate or chlorate of potassa can be had in the solid form, the first may be known by its ready deflagration with charcoal in a crucible; the second by putting a drop of sulphuric acid on a mixture of the salt with sugar, which it instantly ignites.

4. *Ammonia and its salts.* They all act rapidly as irritant poisons, and have besides a violent effect on the nervous system, especially on the nerves of the spinal cord. This last effect is principally produced by pure ammonia and its carbonate. Convulsions are caused by the too long continued inhalation of the vapour of ammonia, which has several times proved fatal to man, terminating in severe bronchitis. For this species of poisoning, muriatic acid vapour is the best remedy. On the reception of carbonate of ammonia in the stomach, we should administer diluted vinegar instantly.

We detect the presence of ammonial vapour by the smell, and by a rod dipt in muriatic acid, which gives rise to white fumes of muriate of ammonia.

5. *Alkaline sulphurets* are all poisonous, chiefly from the

readiness with which they give out a large quantity of sulphuretted hydrogen gas, which is poisonous when inhaled, and when injected in quantity into the alimentary canal. The villous coat of the stomach, in cases of poisoning by alkaline sulphurets, resembles in colour the skin of a toad, and the muscular coat is congested with blood. The alkaline sulphurets act as narcotico-acrid poisons. Their presence is ascertained by a weak acid, and exposing a piece of paper dipt in sugar of lead to the fumes.

Acid Poisons.

III. Acid Poisons. The three mineral acids are only poisonous from their corrosive qualities, destroying rapidly the tissues to which they are applied.

1. *Sulphuric acid*, when strong, decomposes and blackens animal matters by evolving their carbon. It disorganises the fauces, gullet, and stomach; when not speedily fatal it lays the foundation of stricture of the gullet, and the patient is long harassed by dysuria and constipation. It is a felony to throw acid maliciously in the face.

2. *Nitric acid* destroys the animal tissues, and gives them a yellow hue, especially in the fauces, and when applied to the skin.

3. *Muriatic acid* destroys the tissues also, but renders the fauces usually whitish, as if the surface were of ivory. The symptoms produced by the three acids are similar, and the best remedies are the same for all, viz.—the copious use of mixtures of chalk or magnesia with milk.

The three acids destroy the clothes, corroding them when strong, and when diluted, staining them of a reddish brown. This circumstance becomes of importance in cases of maliciously throwing acid on any person, when no part of the acid liquid has been preserved. The stained portions of clothes, soaked in distilled water, will give out the acid; if sulphuric acid be present, it is best detected by nitrate of baryta, which gives a white precipitate, insoluble in pure nitric acid. Muriatic acid is detected by the addition of nitrate of silver, which throws down insoluble muriate of silver. Nitric acid is best recognised by its effect in destroying the colour of sulphate of indigo, when heated with it in a tube.

4. *Oxalic acid* is a most deadly poison. It differs from other acids derived from the vegetable kingdom in not containing hydrogen; being like the mineral acids, a binary compound. Its taste is so intensely sour that it cannot be employed as a secret poison; but it has been swallowed by mistake for sulphate of magnesia, so as to prove fatal. Its alkaline salts are almost equally poisonous, especially the binoxalate of potassa, or salt of *sorrel*, and they are speedily fatal when applied to wounds. Oxalic acid renders the tongue red and inflamed, and it corrodes the stomach; burning pain in the primæ viæ speedily come on, cold clammy sweats, a faint and fluttering pulse succeed, and palsy of the heart soon appears; proving that this substance is not only an acrid but a true narcotic. Unfortunately its effects are so violent and sudden that there can little be done by art to save the patient. Instant evacuation of the stomach, and the exhibition of chalk mixtures are the best means to be employed. Even when the person survives the immediate effects, he often dies of the inflammation or the corrosion of the alimentary canal.

The best mode of detecting oxalic acid is to precipitate portions of it by solutions of lime and magnesia. The precipitate by the first is not decomposable by any acid: sulphate of copper gives a precipitate with oxalic acid, insoluble in a little muriatic acid; and the precipitate with nitrate of silver, when dried, deflagrates with a gentle heat.

Simple Substances with Poisonous Qualities.

IV.—Simple Substances with Poisonous Qualities.

1. *Phosphorus*, even in very small quantities, is poisonous: two grains have proved fatal to a man. In that case there were sugillations on the belly and thighs, the scrotum was bluish and phosphorescent, the chest contained much fluid, dark blood, and the muscular coat of the stomach appeared inflamed, with dark spots about the cardiac and pyloric orifices. Evacuation of the stomach, and the administration of mucilaginous, but not oleaginous substances, are all the means we should employ to give relief in such cases. When the patient lives for some time, it will be difficult to detect the poison, unless the morbid appearances above noted may be considered as characteristic. Solid phosphorus is easily detected, by its inflammability.

2. *Iodine*, and *Hydriodate of Potassa*, are active substances, which, if given in excess, are apt to produce irritation of the system: vomiting, excessive languor, a feeble pulse, pains in the stomach, and cramps in the limbs; bilious vomiting and purging have followed large doses of iodine. It stimulates the liver, causes absorption of indolent glandular tumours; and, it is said, that its long-continued use has caused the disappearance of the testes and mammæ.

In dogs poisoned by it, the stomach was found inflamed, with numerous ulcerated points on its villous coat. No antidote is known. Its detection is easy. Boiled solutions of starch are delicate tests of the presence of iodine, or of hydriodic acid, by the intense blue colour produced. If hydriodate of potassa be present, the colour is evolved, on adding to the starch a drop or two of sulphuric acid.

3. *Bromine* is more poisonous than the last substance, but it is so rare a substance, that it is unnecessary to describe its effects or mode of detection.

Gaseous Poisons.

V.—Gaseous Poisons.—Of these some are fatal from the irritation they produce, A; others are narcotic, B.

A.

1. *Chlorine.*—This gas destroys life, if incautiously inhaled, by the irritation it produces. It causes violent constriction of the epiglottis, and severe pain in the chest, even when diluted. It disinfects air contaminated by animal emanations. Its solution in water kills dogs; and when injected into a vein, it speedily destroys life. It is most certainly detected by its smell.

2. *Hydrochloric gas*, or *muriatic acid gas*, is still more irritating and destructive. It is largely emitted in the manufacture of soda from salt, and is then most hostile to vegetation; $\frac{1}{36000}$ of it contaminating the atmosphere, so as to destroy plants.

3. *Sulphurous acid gas* is also most suffocating; is, even when much diluted, very destructive to vegetation; and has, as emanating from burning sulphur, sometimes been employed to commit infanticide. It renders the lungs very livid.

4. *Nitric oxide, and nitrous acid vapour*, are poisonous irritant gases, that cannot be respired, unless largely diluted. The attempt to respire the former nearly proved fatal to Davy. The fumes of the latter have accidentally proved fatal to individuals, producing burning sensations in the throat and chest, an expectoration of yellowish matter, and alvine dejections of a bright yellow colour. Before death the body becomes livid, the breathing laborious. Vapour of ammonia cautiously inhaled may relieve from the effects of this gas, of hydrochloric, and of sulphurous acid gases: but we have no means of detecting any of these poisonous gases, in the small quantity they ever can exist in the human chest, except by the sense of smell.

5. *Ammonia* is not only irritating when received into the lungs, but is, as we have already said, narcotico-acrid.

B.

6. *Nitrous Oxide*, the exhilarating gas of Davy, is narcotic, yet can scarcely be considered as poisonous, since it may be inhaled several times a-day without injury; but it seems to have a tendency to cause cerebral congestion.

7. *Sulphuretted Hydrogen* is one of the most poisonous of gases, destroying life when injected into the intestines, or into the cellular tissue, when received into the lungs, or even when extensively applied to the surface of the body. It is largely given out in the corruption of some kinds of animal matter. Many serious accidents from this gas have happened in clearing out the Parisian *fosses d'aisance.* The symptoms are instantaneous asphyxia, with discharges of bloody froth from the mouth, and convulsive movements of the limbs; motion and sensibility soon cease, the lips become livid, the eyes close, and lose their lustre, the surface becomes cold, the action of the heart is tumultuous, then feeble, and before death complete tetanus often comes on. Even when the gas does not kill, it produces severe tormina, nausea, and drowsiness. The body of one killed by it quickly becomes putrid; the skin is livid, and soon meteorized; the brain tender, and of a greenish hue. The proper treatment of persons suffering from this gas is to carry them into pure air, to dash cold water and vinegar over the body, to rub the surface diligently with warm flannels, but to admit air freely to the surface, while the palms and soles are to be strongly brushed. Lavements of cold water and vinegar should be first used, and then lavements containing common salt; when the heart beats violently blood should be abstracted.

This gas is well known by its smell resembling that of rotten eggs. Solutions of sugar of lead are very delicate tests of its presence in minute quantity.

8. *Carburetted Hydrogen*, of various qualities, is given out by stagnant waters. It is one of the results of combustion, and is abundantly produced in coal mines, where it is the formidable *fire damp.* When the atmosphere is much contaminated with it, it oppresses the breathing, and produces headache and giddiness. When mixed in the proportion of about $\frac{1}{12}$, with the atmosphere of mines, it will explode on the approach of a flame; yet in such an atmosphere persons will continue to work for some time with impunity; but even if there be no risk of explosion, the narcotic effects of the gas begin to be perceived on those long exposed to it.

9. *Carbonic Oxide*, mixed with other gases, is given out by burning fuel, especially if moist, and burning slowly. It scarcely becomes an object to the toxicologist in its pure state. It is inflammable, rather lighter than atmospheric air, and has a disagreeable smell. It may be respired when diluted; but produces temporary intoxication, and when injected into the veins gives the blood a brown colour.

10. *Carbonic Acid.*—This gas is well known to be heavier than atmospheric air, to be totally irrespirable when pure, and to be speedily fatal to animals plunged in it. It is always present in the air in minute quantity; but is largely given out by the burning of all sorts of fuel, is produced in every species of fermentation, is formed in the respiration of all animals, and, under certain circumstances, it is given out by plants, particularly in the dark. From these sources, the air, in confined situations, may become impregnated with it, in a proportion inconsistent with the safety of man. Numerous instances of its fatal effects have been observed in the neighbourhood of large fires, in breweries, in crowded apartments; and in rooms where many plants are growing, it is unhealthy to sleep. When a confined atmosphere is much mixed with it, uneasy respiration is speedily felt, and the person may escape the danger by seeking the open air; but at other times drowsiness or stupor comes on, before any warning is given, and the individual loses the power of attempting his escape. When the gas is undiluted, it is almost immediately fatal to animals immersed in it; and even if the animal be made to respire pure air, while the whole body, except the head, is immersed in carbonic acid, life will be extinguished. After death from this gas, the features remain placid, the eyes open and brilliant, the body long retains its heat and flexibility. When the person has not been exposed long enough to extinguish life, the breathing may be stertorous and oppressive, the face flushed, the pulse feeble, the eyes prominent and wildly rolling about, the tongue swollen, and the saliva flowing out of the mouth.

The proper treatment consists in removing the patient into the open air, or into a well-ventilated room; the surface should be sprinkled with vinegar and water, and every few minutes rubbed dry with hot towels. If the valve bellows be at hand, the foul air should be first drawn from the lungs, and its place immediately supplied by fresh air, thrown in by the same machine. This alternation may be two or three times repeated, and then we should imitate natural respiration as much as possible, throwing in air by the bellows, and aiding the expulsion of the air by gentle pressure on the chest. Brushing the soles of the feet and palms of the hands with stiff brushes, stimulating the nose by a feather, or by ammonia, are useful auxiliaries. When animation is restored, it is time enough to put the patient to bed.

Vegetable Poisons.

VI.—VEGETABLE POISONS.—These include most of the narcotic and narcotico-acrid poisons of Orfila. Narcotism begins with a sense of fulness in the head, then succeed a sort of intoxication, dizziness, headache, loss of voluntary motion, almost amounting to paralysis, sometimes convulsions, and finally, stupor and coma. These symptoms may not all be present; for each poison has its peculiar modification of the general symptoms. The *post mortem* examinations of those who perish by narcotic poisons do not generally throw much light on their mode of destroying life; and there are some diseases that bear considerable resemblance to narcotism. Thus, *Apoplexy* chiefly differs in there having usually been some warning before the fatal attack, and in coming on during a meal. Narcotism is generally perceived from half an hour to one hour, or more, after taking the poison. Narcotism is more gradual than apoplexy, and at first the person may be roused from his stupor. Apoplectics generally survive for a day, or often much longer. *Epilepsy* may generally be distinguished by the history of the case, by the abruptness of the attack, by the person being instantly rendered insensible, and by its rarely proving fatal on the first attack. One species of fatal *syncope* is more difficult to be distinguished from narcotism; and if it has not been witnessed, we do not know how it can be recognised after death.

1. *Opium.*—The deadly effects of this substance have been long known; and it was supposed to be a proximate vegetable principle, simple in its nature, and peculiar in its effects. Modern chemistry has shewn that opium, like many other active vegetable substances, owes its qualities to an *alkaloid*, which may be separated, by chemical processes, from many other ingredients. The first of these alkaloids was detected in opium about 1812; and the care with which this important drug has been since examined, has shewn it to be an exceedingly compound substance, consisting of not less than of sixteen, or perhaps of seventeen different vegetable principles, of which nine are crystallizable. Of these, in a toxicological point of view, the most important are *Morphia* and *Meconic acid.* These two ingredients appear to exist in combination in opium; and when magnesia is added to a watery solution of opium, an insoluble meconate of magnesia is formed, from which the morphia, sparingly soluble in water, is taken up by alcohol; or, if we add muriate of lime to the liquid, instead of magnesia, we obtain meconate of lime, as an insoluble precipitate, and a soluble muriate of morphia; which last, when purified by several nice chemical manipulations, is obtained in minute, white, silky crystals. This is the valuable part

of opium to the medical practitioner, as it is powerfully hypnotic, and is less liable to cause headache, nausea, and itching of the skin, than crude opium.

When either this substance or opium are administered in an over-dose, the symptoms are drowsiness and insensibility, but this state is often preceded by a slight excitement: the face assumes a ghastly hue, the jaw falls, the eye-lids remain half open, the pupils are strongly contracted, stupor and complete coma succeed; convulsions are rare in adults, but often are seen in infants. Adults in general die easy from this poison. Opium produces its fatal effect, however introduced into the system, and even when applied to a raw surface, has destroyed life. Morphia is stronger than opium, in the proportion of 6 to 1.

The principal morbid appearances are great turgescence of the vessels of the brain, and sometimes serous effusion between its membranes, or in its ventricles; the lungs are gorged with blood, the stomach rarely appears inflamed, the blood is found fluid in the heart, and the body runs rapidly to decay.

Evacuation by the stomach pump, or by emetics, is the remedy chiefly to be trusted; and after the patient is roused, we must prevent him falling asleep while any tendency to stupor is perceived. Artificial respiration appears to have saved one person who was found comatose. No antidote is known.

The best tests of crude opium are those which shew the presence of morphia and meconic acid. The contents of the stomach, in a case of the poisoning with opium, may have the smell of that drug. The whole should be emptied into a clean mortar, and reduced to a thin pulp by the addition of distilled water; acidulate the whole with acetic acid, strain and filter, then reduce the liquor to the consistence of a syrup by a gentle heat: add alcohol gradually, boil, and filter when cold. The spirituous solution will contain all the morphia. Again, evaporate to the consistence of syrup, and add magnesia, which will throw down meconate of magnesia and the morphia in the form of a greyish powder, which may be freed from much of its colouring matter, by washing it with cold water, and then with cold proof spirit. The morphia may now be separated from the meconate of magnesia by hot strong alcohol: concentrate this last solution, which will have a bitter taste, which, on adding a drop of nitric acid, will strike an orange yellow colour, soon passing to golden yellow; and will give a duck-blue with permuriate of iron.

The meconate should be decomposed by muriate of baryta, which will form an insoluble meconate of baryta; from which the addition of very diluted sulphuric acid separates the meconic acid. This acid has a silky lusture in the state of crystals, and affords, with permuriate of iron, a very intense red. There is only one source of fallacy in operating with meconic acid from the human stomach, which must be guarded against, namely, that the sulphocyanates of the alkalis precipitate permuriate of iron of a red colour, and some of the secretions, as the saliva contain a sulpho-cyanate. If the solution of morphia be strong there is no danger of mistake; because of the intensity of the colour produced. Professor Forbes has also shewn that the two solutions affect the prismatic spectrum in a different manner; though perhaps this test is less applicable to medico-legal causes, where the quantity of ingredients is generally very minute.

2. *Hyoscyamus niger.* The whole plant is narcotic, especially the roots, which have several times caused fatal effects, by being eaten instead of parsnips. The symptoms are active delirium, in which persons have danced and reeled about until stupor supervened. In persons fully under this stupor, stimuli cease to rouse, and the eye is insensible to light, or even to being touched. Emetics are the reme dies; but we have no particular tests of this poison.

3. Besides Hyoscyamus, other *solaneæ* are narcotic. This is especially the case with *solanum nigrum* and *s. mammosum.* Both owe their activity to an alkaloid, *Solanea;* which is capable of exciting vomiting, hurried respiration and stupor.

4. *Lactuca virosa* is a poisonous plant, with a juice that is highly narcotic, and has the smell of opium. This juice, when inspissated, forms the *lactucarium* of the shops, which was at first derived from the *lactuca sativa,* but is obtained in greater quantity, and of precisely the same quality, from *l. virosa.* Stupor and coma follow an over-dose of lactucarium.

5. *Hydrocyanic acid,* or *Prussic acid* forms the poisonous ingredient in an important class of vegetables. It is yielded by the kernels of the *bitter almond,* and of several other species of that genus; by the leaves of the cherry laurel, or *prunus lauro-cerasus,* by the *prunus padus;* and probably is contained in the seeds of the *pomaceæ,* and in all vegetable productions with the odour of bitter almonds. The acid, when concentrated, is the most deadly of all poisons; producing almost instant death, whether swallowed or introduced by a wound. Even the diluted hydrocyanic acid of the apothecary's shop is fatal in a very moderate dose; and the essential oil of bitter almonds is not less so. An infusion of the leaves of cherry-laurel is a very deadly poison: bitter almonds have sometimes proved fatal; and the same effect has followed on eating the blossoms of the common peach, *prunus persica,* in a salad. When the preparation is concentrated, the death is very speedy: the breathing immediately becomes laborious, convulsive movements of the limbs come on; in dogs it ends in violent tetanus. After death the eyes are glistening, the pupils dilated, the muscles of the spinal column stiff, the countenance pale and often composed, the abdomen drawn in; the veins of the brain are found to be loaded with black blood, and the blood in the heart and great vessels is generally fluid. In some instances the blood and cavities of the body have exhaled a strong odour of prussic acid; and the blood has been said occasionally to have exhibited a bluish tint when the strong acid has been administered. The bile has often been observed to be of a dark blue hue in such cases.

No remedy can be of service in poisoning by this substance, unless instantly administered: but ammonia appears to have a great power in alleviating the symptoms when the quantity of hydrocyanic acid has not been very great. Ammonia diluted with water should be introduced into the stomach; its fumes sufficiently diluted with air allowed to enter the lungs, taking care not to excoriate the air passages by the too free use of the ammonia. Another very powerful antidote is chlorine. It is most advantageous to employ the vapour of water containing about one fourth part of its volume of chlorine gas. This may be inspired without risk; it has saved the lower animals when the poison had been administered for five minutes before its application, even after the convulsive stage had passed, and that of insensibility had supervened. In Orfila's experiments, in ten minutes after inspiring diluted chlorine in this manner, the recovery of the animals was certain. Herbst of Göttingen states, that dashing cold water on the surface of the body, is a powerful antidote in such cases: it is most successful *before* the convulsive stage, but is useful during the spasms.

The tests of hydrocyanic acid are certain when we can obtain it in quantity: but when we must look for it in the body, the smell is its best criterion. The stomach and the blood will sometimes have its peculiar odour for more than three days after death; and if the body has been buried within twenty-four hours, the odour will occasionally remain till the eighth day. When we can obtain a little of the liquid acid; nitrate of silver is a very delicate test. A white precipitate is formed, which, when dried and heated in a tube, gives off *cyanogene*, a gas that burns with a rose-coloured flame. If we add to the suspected liquid sulphate of copper, a rich emerald green solution is formed: and if to another portion of the liquor we previously add a drop or two of potassa, that test will throw down a greenish salt, which is partially dissolved by hydrochloric acid, leaving behind a cyanide of copper, which will yield cyanogene like the precipitate of silver. This test will detect prussic acid in 20,000 times its weight of water.

Strychnia, and the Plants from which it is obtained.—This alkaloid, and the plants producing it, all act in the same manner, being very poisonous, and causing speedily severe spasms, ending in tetanus and asphyxia from fixation of the muscles of respiration. Strychnia was first obtained from the seeds of *Strychnos nux vomica* in 1818, by Pelletier and Caventou; but it exists in still larger quantity in those of *Strychnos Ignatii.* The powder of the seeds is first exposed to the action of nitric æther, to separate a large quantity of oil, and is then digested with diluted sulphuric acid; the acid is next separated by means of lime or magnesia, and the alkaloid taken up by boiling alkohol. This was supposed to be pure *strychnia;* but it was afterwards found to be mixed with another alkaloid of somewhat similar properties, which was first obtained from a bark imported into Europe as that of the true angostura bark, or *Galipea officinalis.* It was found to be very poisonous, and was supposed to be the bark of *Brucea antidysenterica.* Hence this new alkaloid was named *Brucia.* But it has been more lately discovered that the bark was not a production of South America, but of India, and really was the bark of *Strychnos nux vomica*, which contains a larger quantity of brucia, with some strychnine, than the seeds of the plant. According to some, the poisonous energy of the strychnia to brucia is 6 to 1; others say as 24 to 1. The two alkaloids, when mixed, as they always are in the strychnia of the shops, may be separated by dissolving the impure salt in very diluted nitric acid to saturation, and crystallizing the solution; the nitrate of brucia forms short, solid prisms, while the salt of strychnia exists in soft silky tufts, which, by agitation, may be poured off with the mother water from the crystal of nitrate of brucia. Both alkaloids may be obtained pure by carbonate of soda, and taken up by boiling alkohol.

Pure strychnia is a most deadly poison: a single grain would probably destroy a man, and even less if inserted in a wound; but it is still more fatal to dogs and to cold-blooded animals. Yet this energetic substance is used, in minute doses of one-eighth grain, as an internal remedy, and also externally, for the cure of paralysis; but its effects must be carefully watched. Its taste is so intensely bitter that it may be thus detected when diluted in 100,000 times its weight of water. No antidote is known for this deadly poison, though some have supposed that iodine may be useful, as in some other instances of vegetable poisons.

The powder of the seeds of *Strychnos nux vomica*, or of *S. Ignatii*, are deadly poisons. Fifteen grains of the former, and still less of the latter, have proved fatal to man, with tetanic symptoms, after anxiety, spasms of the muscles of the limbs, rigidity of the spinal column, livid face, and impossibility of breathing. These symptoms come on in paroxysms, with intervals of relaxation that become shorter towards the fatal termination. The intervals are marked by nausea, profuse perspiration, and a very feeble pulse; and the victim from a large dose seldom lives an hour. When the death is rapid, the body exhibits little marks of inflammation; but when it has been lingering, the stomach shows traces of violent inflammation in its violet colour, and in some cases gangrene, with a serous effusion in the head and spine, while the blood generally remains fluid. The human body usually retains the rigidity of the muscles after death; but in dogs they have sometimes lost their stiffness just after death.

The celebrated Javan poison is prepared from the juice of *Antiaris toxicaria* and *Strychnos tieuté*, or *chetik*, plants belonging to the natural order of *Apocyneæ;* and another plant of the same order, *Cerbera tanghin*, is said to be so poisonous that a single seed will destroy twenty persons.

The *woorali*, or *wourara* poison of South America, has been found by Schomburgh to be prepared from a decoction of a new *Strychnos*, which he names *S. toxicaria;* and we are informed by Hillhouse and Waterton, that the Indians, during its inspissation, add the juice of bulbous roots and the poison of snakes. We have found very small quantities of this poison, though kept for years, speedily to destroy animals, without violent convulsions.

It becomes of much importance to be able to detect the administration of strychnia and brucia; and the following is an outline of the method, premising that they are less liable to lose their qualities by decomposition in the dead body, than most of the vegetable alkaloids, and may be detected in very minute quantity.

When the powdered seeds of any of the *Strychneæ* are administered, they are usually found adherent to the coats of the stomach, and may be recognised by giving an intensely bitter taste to alkohol, and by forming a deep yellow colour with nitric acid; and the alkaloids may be obtained from them as above.

Strychnia and brucia may be separated from the contents of the stomach by boiling that with vinegar, which will dissolve the alkaloids, while it coagulates the animal matters present; and the mass in the filter may be again boiled with alkohol, and this filtered liquid added to the acetous solution, concentrated by a moderate heat, and the residue will have an intensely bitter taste. 1. To one portion add nitric acid, which will, if brucia be present, give a deep yellow colour. 2. To another portion add chloride of gold, which will throw down a rich yellow precipitate with strychnia; but brucia is not precipitated by this reagent. 3. Acidulate bichromate of potass with sulphuric acid, and add this to a third portion: no precipitate falls; but where strychnia is present, the mixture becomes of a pale blue colour, and retains its transparency. 4. The most decided test of all is the introduction of a few drops of the liquid into the thorax of a living frog, as proposed by Dr Marshall Hall; and even the $\frac{1}{18000}$th of a grain of strychnia will thus produce violent convulsions in the animal.

7. *Tobacco*, a well known narcotic, of difficult detection, except by the smell. Nicotine is its poison.

8. *Atropa Belladonna*, or deadly nightshade, is a strong narcotic poison. All the plant is poisonous, especially the leaves and the fruit. The symptoms produced are delirium, dilated pupils, and loss of vision. Sometimes it causes hysterical bursts of laughter; the lips, tongue, and throat are parched; there is a great sense of sinking, with tremulous movements of the hands; but convulsions are rare. Many instances of poisoning have happened from eating the berries and the young shoots. The active principle is an alkaloid, *atropia.*

9. *Datura Stramonium* is another poison sometimes employed on the Continent to facilitate robbery or rape; and in this country it has been administered by mistake. It owes its activity to an alkaloid, *daturia*, which abounds also in *D. tatula.* The extract of stramonium produces dryness of the fauces, intoxication, and active delirium, with cerebral congestion.

10. Various *umbelliferous plants* are poisonous; such as *Conium maculatum*, *Æthusa Cynapium*, and *Lactuca virosa.* The roots and leaves contain a poisonous juice; and the symptoms are those of narcotics, with some degree of irritation. Various authors have spoken of the *Œnanthe crocata* as very poisonous; but Dr Christison gave it largely

to dogs without killing them. *Conium maculatum* owes its activity to an oily alkaline principle, *conia*, which smells strongly of mice, and becomes, though a clear liquid when cold, opaque on being heated.

11. Several of the *Ranunculaceæ* are acrid and narcotic, as the *Ranunculus sceleratus, R. flammula, R. bulbosus, R. lingua, R. acris*, and *R. arvensis;* but we have no mode of detecting their poison.

12. *Aconitum napellus* produces delirium and stupor, with burning in the throat, vomiting, and purging.

13. *Helleborus niger* is a narcotico-acrid poison of great activity.

14. Several other poisonous plants may be mentioned, such as *Anemone pulsatilla* and *Cytisus laburnum;* the seeds of the latter are narcotic. In all these cases the best remedies are emetics.

15. *Digitalis purpurea* owes its activity to *digitalia*, an alkaloid which may be obtained from it. The chief characteristic of digitalis is its extraordinary power in reducing the force and frequency of the pulse; on which account it is used in medicine; but it is poisonous even in small doses.

16. The other narcotico-acrid poisons of the vegetable kingdom we shall briefly notice, indicating such as have yielded alkaloids to analysis. Of these, *Menispermum cocculus* is one, the active principle of which is *picrotoxia: Delphinium staphysagria*, the seeds of which yield *delphinia; Chelidonium majus; Arum maculatum; Juniperus sabina; Veratrum album*, which yields *veratria*, an alkaloid lately introduced as an external application, and nearly resembling another poisonous alkaloid, *colchicia*, obtained from *Colchicum autumnale; Bryonia alba*, said to afford *bryonina; Euphorbia officinarum; Hippomane mancinella;* various species of *Jatropha*, which yet by cooking yield wholesome food; the seeds of *Ricinus communis;* seeds of *Croton tiglium; Cucumis colocynthis; Momordica elaterium; Scilla maritima;* various species of *Daphne;* several species of *Rhus; Hebradendron gambogioides; Convolvulus jalapa*, and *C. scammonea*. To these some add *Narcissus pseudo-Narcissus, Gratiola officinalis, Caltha palustris*, and *Lobelia inflata*.

17. *Poisonous Fungi.*—Several of this natural order are poisonous, especially those belonging to the genera *Amanita* and *Agaricus*. Their poisonous qualities appear to depend on two principles; one of which is volatile, and disappears on boiling, drying, or macerating in a weak acid. To this principle Le Tellier ascribes the irritant quality of poisonous mushrooms. The other is not volatile, is soluble in water, unites with some acids into crystallizable compounds, and appears to be an alkaloid now termed *fungia;* on this the narcotic properties of these plants depend. The time in which the symptoms occur, after the fungi have been eaten, is very various; often not until twelve or even twenty-four hours. The sufferers are often relieved by vomiting; but if not, the surface becomes livid and cold, violent colic ensues, and death is preceded by delirium and deep coma. The corpse is livid all over, the blood fluid, and sanguine discharges are apt to flow from the mouth, nose, and eyes.

18. *Secale cornutum.*—The *ergot of rye* produces, when eaten in bread, many of the symptoms of mushroom poison. Decandolle ascribes this disease of grain to a fungus of the genus *Sclerotium;* and it has been found to yield a principle resembling fungia. The tendency of this substance to produce dry gangrene is generally admitted by German and French writers. There is a learned dissertation on it by Dr Wiggers, in which its fungoid origin, and its peculiar action in promoting the expulsive efforts of the gravid uterus, seem to be established.

19. *Alkohol and Æther* may be here considered, as being derived by art from vegetable matter. They are well-known narcotics, producing at first intoxication, and afterwards stupor and cerebral congestion. They are also irritants; the stomach of persons killed by them being often inflamed. When the moderate use of spirit does not produce death, it may give rise to *delirium tremens*. The smell of spirit is often perceived in the cavities of the chest and abdomen of those who have died from drinking. The stomach-pump and milk are the best remedies.

20. *Camphor*, a concrete essential oil, has pretty strong narcotic qualities. It is best detected by its peculiar odour.

VII.—Animal Poisons.

Animal poisons.

1. *Cantharides.*— An acrid poison, is contained in the body of the *Cantharis vesicatoria*. It is found to reside in a whitish matter, resembling spermaceti in colour and consistence, which is united to three other marked principles. The first is a green oil, soluble in spirit, but not in water; the second a blackish matter, soluble in water, not in spirit; the third a yellowish viscid matter, soluble both in water and in spirit. This last is united in the insect with *cantharidine*, and renders it soluble in water, which it is not when pure.

The symptoms of poisoning by cantharides are intense burning heat in the primæ viæ, painful deglutition, pain in the stomach and bowels, bloody vomiting, painful micturition, and priapism, intense desire to void urine, and distressing pain in the whole urinary organs: frightful convulsions and tetanic spasms usher in the fatal termination. When the flies in substance have been swallowed, the fragments of their green *elytra* are found adhering to the villous coat of the stomach; and this has been observed even after the body has been buried for months. There is no antidote for this poison. Evacuants and mucilages are the best remedies. Oil given by the mouth increases the evil by dissolving the cantharidine; but oil thrown into the bladder is useful in allaying the irritation.

2. *Fish Poison.*—This singular subject is little understood, except that, in certain seas, and in certain seasons, fishes, at other times wholesome, prove deadly poisons. This is chiefly the case with the *yellow-billed sprat*, the *barracuta*, the *grey snapper*, the *Sparus venenosus*, and *grey labrus* of the West Indies; with several species of *Diodon* and *Tetrodon*, and with *Aplodactylus punctatus*, of the Southern Ocean. The rapidity and fatality of the poison has been described by Chisholm, Ferguson, and Thomas. The symptoms are,—irritation in the throat, tingling of the surface, burning heat in the stomach and bowels, colic, nausea, spasms, giddiness, coma, and death. It is said that persons have died whilst masticating a portion of the fish, ere any of it was swallowed. The juice of the sugar-cane, and various sweet liqueurs, are said to be useful in the slighter cases.

Fishes in this country are sometimes poisonous; and mussels have occasionally with us produced death, with less rapidity, but with symptoms of the same kind. The cause of the poisonous quality of fish is, with some probability, attributed to their having fed on acrid mollusca.

The flesh of birds is occasionally poisonous; as happens to the *Phasinanidæ* of North America when they have fed on the buds of the *Kalmia latifolia*. The honey of the bee, in like manner, is poisonous when it has fed on the sugar of the *Rhododendron* and *Kalmia*, as is described by Xenophon, Pallas, and Dr Smith Barton. In the former case the honey produced a species of madness; in the latter the symptoms were similar to what occurred to the soldiers of Xenophon.

3. *Animals have a poison generated in them by disease*, which is capable of infecting those who eat, or even touch their flesh. The best known instances of this is in the *Pestis bovilla* or *murrain* among domestic animals, by which their flesh and juices become deadly poison to other ani-

mals. This appears somewhat analogous to the accidents that happen in dissection.

4. *The bites of rabid animals* belong to the same class of poisons. The bite, for instance, of a rabid dog will destroy other animals; after some time they become delirious, than paralytic, and invariably die rabid. In man similar symptoms occur, to which is superadded hydrophobia,—a symptom never observed by Mr Youatt in any animal except *man.* Excision of the wound, or destruction of the part by caustic, is the best prophylactic; *Belladonna* and *Scutellaria lateriflora* seem to have some preventive power, according to the same authority; and excessive bleeding seems to have arrested or cured the disease in India.

5. *Bites of Snakes.*—Poisonous snakes are provided with two or more teeth placed on a moveable bone, on each side of the upper jaw, and corresponding to the maxillary bones of other animals. These teeth or fangs are hollow, and have their roots connected with a duct that conveys the poison from a bag placed under the principal muscles that close the jaws; so that when the animal bites, the poison is squeezed from the bag, and is instilled, through the hollow of the fangs, into the wound. The symptoms, in general, are in proportion to the quantity of the poison compared to the size of the animal bitten; the smallest animals suffering most. The general symptoms are,—pain in the part wounded, trembling, weakened respiration and circulation, and coma. The most poisonous snakes are the *rattlesnake* and *trigonocephali* of America, and the *cobra de capello* of India: the *viper* of this country and of France sometimes produces fatal accidents. Excision of the part, sucking, or cupping the wound are to be tried; and both ammonia and arsenic given internally appear to have considerable power in curing the bites even of the most deadly snakes.

6. *The stings and bites of Arachnidæ and Insecta* are poisons of a similar kind. The complex apparatus of the sting of the bee and wasp convey poison to the wound so acrid that horses, asses, and also men, have died from numerous stings. The sting of the scorpion, and bite of *Scolopendra morsitans,* as well as of spiders, are inflicted with a poisoned apparatus analogous in structure to the fangs of snakes.

Imaginary poisonings.

VIII. Imaginary, Pretended, and Imputed Poisonings, require much patience and attention on the part of the medical jurist. To them no general rule can be applied, but they must be treated according to the nature of each peculiar case.

PART II.—MEDICAL POLICE.

SECTION I.—CIRCUMSTANCES AFFECTING THE HEALTH OF INDIVIDUALS.

Cleanliness.

I. Cleanliness.—This subject may be considered under three heads.

1. *Personal Cleanliness* is valued by all nations in proportion to their advance in civilization, and exercises an important influence on the health of individuals. Most savage nations are disgustingly deficient in this virtue; but the polished nations of antiquity paid great attention to it, as is evinced by their general use of baths, the stupendous ruins of which still surprise us in the remains of their cities. In modern times, especially in Great Britain, warm and cold bathing are far less employed than is desirable; and we cannot help regretting the want of public baths for all ranks, especially in our manufacturing towns, where the luxury of warm or tepid bathing might be very cheaply obtained, by collecting the waste water from the *condensing backs* of steam-engines. Bathing, by removing sordes and remains of perspiration, keeps the skin in a fit state for its important functions. Public baths should be established in every town, and all children should be taught to swim. The warm and vapour baths of Northern Europe prove how cheaply such luxuries might be obtained for the great mass of the community.

2. *Domestic Cleanliness* is perhaps better understood by the Dutch and the English than by any other nations in the world. This virtue has been long practised in Holland, but is comparatively only of late origin in Britain. The picture which Erasmus draws of English manners is not very flattering; and our own historians prove that it was not until after the civil wars of the seventeenth century that the English became a cleanly people. Now no nation can surpass them in domestic cleanliness, and none equal them in domestic comfort. The effect on the health of the inhabitants is shown by the less frequent attacks of severe epidemic diseases in modern times, and perhaps also by the increased value of life annuities.

3. *Ventilation of Habitations* is one important part of domestic economy, now better understood; and Strutt, Sylvester, and Murray have taught us how ventilation may be combined with warmth. The renewal of the air, vitiated by respiration and combustion, is secured by simple contrivances, and the air admitted into apartments is warmed by passing between a close stove or cockle and an exterior covering.

Aliment.

II. Aliment.—Under this head may be considered,—

1. *Preparation of Food.*—Alimentary matters are rendered more wholesome and nutritive by cooking; and the mystery of that art is not unworthy of consideration, even were it not also the means of economizing the sustenance, and increasing the gratification of man.

2. *Culinary Utensils* deserve attention here, because the wholesomeness of aliment often is materially affected by them. There is risk of cooking food, especially of the acescent or oleaginous kinds, in copper vessels, though the danger is diminished by keeping the utensils always bright, and not suffering the food to remain in them after removal from the fire. Vessels of lead and pewter should be entirely banished from the kitchen, as they are never without danger, from the ease with which they are acted on by acids. Tinning copper vessels renders them safe as long as the coating of tin lasts; but the vessels usually made of pewter, an alloy that contains lead, should be replaced by those of block-tin or of tinned iron. The objection to the last kind of vessels is their little durability, and the lead solder with which they are put together. Vessels of iron are durable and cheap, but they blacken some kinds of food: this is best obviated by a coating of tin. Vessels of gold and silver are far too expensive for ordinary use; but copper is often covered with a thin plate of silver, forming what is termed plated ware, which is excellent while the silver remains on the copper. A thinner coat of silver is applied in some instances by means of an amalgam of silver, and a similar process is commonly used to gild the inside of silver or of plated ware. *Pottery* is a valuable addition to culinary utensils. It is of all qualities, from the purest porcelain of China or of Europe to the coarsest earthenware. The glazes which contain lead are objectionable where acids are to be used; but if well baked, such glazes are not readily acted on. For chemical experiments the porcelain of China or of Germany, in which there is no lead, is always preferred, and it would be so also for culinary purposes but for the expense. These glazes are made with felspar, or with mixtures of flint and alkalies.

3. *Adulterations of Food* may be accidental or designed. We have just stated how lead and copper may find their way into food; but there are other accidental adulterations. Farina or flour may be rendered unwholesome by the pre-

sence of the *ergot*, the *smut* of wheat, and the seeds of *Lolium temulentum*; which last acts as a narcotic. Flour may also be mixed with sand, from the use of too soft millstones, with other impurities, from want of care in winnowing or grinding; or by fraudulent mixtures of chalk and gypsum. Bread may be mixed with chalk, magnesia, potassa, soda, or alum, to conceal bad flour; and it has been sometimes adulterated with white lead. These adulterations are easily detected. On rubbing down the bread into a pulp with water, the heavy particles will subside to the bottom and may be collected; the alum, alkalies, or lead may be detected by chemical tests. Butcher meat may be unwholesome from disease in the animal, or by long keeping. Butter may be deteriorated by containing too much salt or water. Water may be unwholesome or disagreeable from corrupting animal or vegetable matter; from being too hard,—that is, containing too much saline or earthy ingredients. Soft water may be adulterated by passing through leaden pipes, or standing in cisterns of that metal. Milk may be fraudulently mixed with water, or with magnesia and chalk. Malt liquors have been purposely adulterated by *Cocculus indicus, Lolium temulentum*, &c., to increase their intoxicating qualities. Wines have been chiefly adulterated by brandy, to give them strength; by preparations of lead, to correct acidity and impart astringency. This last ingredient is best detected by a test consisting of a solution of tartaric acid impregnated with sulphuretted hydrogen. The chief adulterations of spirit are by water, which is detected by the hydrometer; and by lead, accidentally introduced from the worms of the stills. Lead is readily thrown down by infusion of galls, which will convert new unwholesome spirits into good spirit. Vinegar is liable to contain lead and copper, from the pipes and cocks through which it flows. These metals are easily detected by sulphuretted hydrogen and ammonia.

Police of drug-shops.

III. POLICE OF APOTHECARIES' SHOPS.—The supply of good drugs is regulated in many countries by the government. Inspectors are appointed, who examine and report on the state of the drugs found in the premises of dealers, and any infringement of the laws is rigorously punished. In our country the inspections are a mere form, of little or no utility. They should be made by persons paid by the state and competent to the task, whose office should be honourable.

Clothing.

IV. CLOTHING.—The importance of paying attention to the qualities of clothing is generally admitted. The advantage of flannel or cotton next the skin to persons of a consumptive habit, or of otherwise delicate constitutions, and also to soldiers and sailors, or other persons whose occupations are laborious, is acknowledged. The use of linen next the skin is suitable for the young and robust; but as persons advance in life, cotton or woollen under-garments are advisable.

1. The *Male Dress* should afford sufficient protection to the parts it covers, and should not impede the free use of the limbs. The covering of the head should defend the eyes from excess of light, and the head from the sun. Anything tight about the neck is injurious. Those who take much exercise will find useful support from broad belts round the waist; especially as they advance in life.

2. The *Female Dress* should keep the body comfortably warm. Compression of the chest and abdomen of females is far too general; and the ribs of most of our ladies are deformed by tight lacing. This practice diminishes the cavity of the chest; it confines the stomach and liver excessively, and has a tendency to contract the width of the pelvis. By the first, consumptive diseases are induced; by the second, the function of digestion is injured; by the last, the perils of child-bed are increased. The practice of tight lacing is ancient. It is severely stigmatized by Juvenal; and is condemned by all modern authors. Excessive exposure of the bust is also too general among women, and often lays the foundation of disease.

Temperance.

V. TEMPERANCE.—Its importance to health, to vigorous youth, and to honoured age, need not be insisted on. Gluttony is not less destructive, and is even more disgusting than drunkenness: both are sure to end in debasement of the mental faculties, and destruction of the bodily health.

Exercise.

VI. EXERCISE.—Regular exercise in the open air is highly conducive to health; and those who are interested in the improvement and happiness of the lower classes in our towns cannot help lamenting the little that has been done to encourage our artizans and shopkeepers to take outdoor exercise in pure air.

The philanthropist must remark with regret the circumscription of the means of enjoying fresh air, which the inclosure of commons and of waste lands near towns and villages has produced, and the discouragement by officious magistrates of the outdoor games and pastimes of the lower orders. Part of the sums so frequently left to endow hospitals and alms-houses would be more rationally expended on gymnasia for the encouragement of healthy sports in the open air, or on public walks for the recreation of our citizens.

Prostitution.

VII. PROSTITUTION.—In most parts of the Continent the state has interfered, not, as is falsely alleged by some, to raise a revenue from this polluted source, but to secure the rising generation, as much as possible, against the fearful consequences of diseases that sap the foundations of a nation's strength, by impairing the sources of a healthy progeny. The unfortunate class of females, who may generally be considered as the victims of male licentiousness, are there regularly registered, and subject to domiciliary visits of the authorities, who send them to hospitals when disease first makes its appearance. The arguments against this practice are not more rational than it would be to forbid the medical practitioner to lend his aid in other cases where the imprudence of the sufferer was the cause of his malady.

Celibacy and marriage.

VIII. CELIBACY AND MARRIAGE.—In the most polished states of antiquity marriage was enjoined by positive enactments, and enforced by penal statutes; in modern times legislators wisely leave it to the sense and discretion of individuals. In fact, the propensity to celibacy is so small in most persons that marriage may be safely entrusted to individual will. The tendency to increase and multiply is so forcible, that it will generally be found to produce a population up to the very limit of the means of providing for children. It was for advocating this philosophical truth, and for pointing out the natural checks to a redundant and miserable, because destitute, population, that Malthus has been abused by sciolists and pretended philanthropists, who appear, from their senseless declamations, either never to have read his works, or not to have comprehended their import.

Lactation.

IX. LACTATION AND CARE OF OFFSPRING.—The important duty of rearing the helpless infant devolves by nature on the female parent; and in general it can never be so well performed by any other individual. In an artificial state of society, however, many females become mothers who are not able to nurse their children. In such cases we would recommend the employment of a wet nurse, as affording the best chance of rearing the infant. The child should not be long fed *exclusively* from the breast, because its stomach should be gradually accustomed to other food before it is weaned. The infant is totally dependent on the care of those around for its preservation. To retain it healthy, it should undergo daily ablutions, have its clothes of suitable warmth, easy, and frequently changed. Its food should be chiefly of milk and farinaceous matter for the first two or three years. It should have regular exercise in the open air; and not be confined in its early years to too sedentary occupations. The dreadful mortality in foundling hospitals proves the importance of the circumstances alluded to under this head.

Profession and trade.

X. Effects of Profession and Trade on Health.—This is a very important consideration, and may be divided into various heads.

1. *Diseases incident to affluent idleness* are chiefly such as arise from indolence and want of some definite object of pursuit: hypochondriasis, tedium vitæ, dyspepsia, gout. For these the best remedies are, rural amusements, intellectual pursuits, mingled with sufficient inducements to take exercise in the open air.

2. *Diseases of Literary Men* are chiefly produced by want of attention to regular exercise in the open air, giving rise to dyspepsia and constipation; by inequalities in the time of eating and sleeping; and by excessive use of the eyes in artificial light. They are best obviated by abridging the hours of study, and mingling sedentary avocations with active and social occupations. Literary men, however, especially in France, have been a long-lived race.

3. *Clergymen* have a wholesome intermixture of sedentary with active duties; and, if their lungs be sound, they are generally long-lived.

4. *Lawyers*, when their occupations are chiefly at the desk, are subject to the diseases of sedentary persons; but barristers, when not excessively harassed by toil, may generally be considered as engaged in a healthy occupation. Many of our judges attain extreme old age.

5. *Medical men*, from the general activity of their pursuits, their knowledge of the causes that promote health, and the wholesome exercise of mind and body induced by their profession, are generally considered as a long-lived class; but in this, as in other learned professions, small account is made of those who die before they have become known, of those who pine away from penury and hope deferred, or whom a desire to better their condition sends abroad to perish on inhospitable or pestilential shores. Yet, taking the whole together, the medical profession is certainly favourable to longevity.

6. *Schoolmasters, Clerks, &c.*, are subject to the usual diseases of sedentary persons, and to those produced by passing a great part of the day in vitiated air, with the sternum leaning on a desk. Such persons should live at some distance from the scene of their labours, that they may be compelled to take exercise in the open air.

7. These observations apply also to *Merchants*, to *Master-manufacturers*, and *Shopkeepers*. A British merchant has, when successful, an enviable life. The morning is dedicated to business, and the afternoon to his family and friends; while his home is usually remote from the crowded streets in which his counting-house is necessarily placed.

8. *The Shopman*, however, generally leads a very different life. He is late and early in the shop, the whole day is spent in serving customers, and in many instances his hours of rest are abridged by the duties of his business, which afford him no time to take exercise in the open air. This is peculiarly hard on young persons, perhaps sent from the country to be immersed in the smoky atmosphere of a crowded, narrow street. Multitudes of both sexes annually fall victims to this change.

9. *Soldiers and Sailors*, when they escape the perils of training to their laborious occupations, are often healthy, if temperate, and if care be taken of their health by their superiors. Their ailments often arise from their own intemperance, as much as from the casualties of their calling. Excessive fatigue is certainly unfavourable to longevity; and when we find very old persons in this class, we may attribute it in a great measure to the iron nature of their constitutions, which have enabled them to resist the hardships to which they must have been subjected in their younger years. Soldiers on duty are more exposed than sailors to wet and cold, to unwholesome climates, and to bad fare. A sailor carries with him his provisions and his change of raiment; and in the British navy he has much attention paid to his health while on board his ship. Long marches are apt to produce diseases of the hip joint, and hernia, especially in young soldiers. The sailor is liable also to hernia from strains in the course of his laborious duty.

10. *Agricultural Labourers* have generally a very healthy occupation. When the returns of their industry afford them sufficient aliment and comfortable clothing, their situation is much more favourable to health than that of the town mechanic. The same may be said of carters, postilions, and coachmen; except that the latter are often exposed at night to the inclemencies of the weather, and are not always remarkable for sobriety.

11. *Quarrymen and Stone-masons* are liable to serious injury from the minute dust they create entering the air passages along with their breath. This often gives rise to a species of consumption; and such persons are seldom long-lived. It affects the stone-masons of Scotland more than those of England: the former work under sheds, the latter in the open air. Marble-cutters for the same reason are unhealthy; and even the employment of a sculptor cannot be considered as a good one for a person of delicate lungs.

12. *Carpenters* and *Joiners* exercise healthy trades, because they require activity, and are freely exposed to the air in many of their operations. It is very different, however, with artizans whose trades are chiefly carried on in a vitiated atmosphere.

13. The trade of the *Weaver* is always rather unhealthy from his working in a confined space; but the introduction of machinery has reduced the pittance of the hand-loom weaver below what can support life with any comfort, and his habitation is proportionally wretched. There is in this occupation exercise to the limbs; but the breast leans against the beam, which, with wretched fare and depressed spirits, render the trade of the weaver unfavourable to health.

14. *Milliners and Tailors* are confined in hot and ill-ventilated rooms, they work too many hours in the day, and often have the natural hours of rest greatly abridged. Milliners are liable to become short-sighted; and the practice of biting the thread generally injures their front teeth. The lives of young females are often sacrificed to this business. Tailors assume a faulty position whilst at work; and the consequence is, that when they walk they have a peculiar strut; the increased power imparted to the muscles of the back, from long supporting the weight of the head, causes the shoulders to be preternaturally drawn back. They are also very subject to phthisis.

15. *Shoemakers* are more healthy; but the pressure of the *last* against the sternum and stomach is sometimes injurious.

16. *Miners and Well-sinkers* are engaged in laborious trades, in which they are exposed for considerable periods to breathe a vitiated atmosphere; and are further liable to the bad effects of inhaling dust, which predisposes to asthma.

17. Artizans working amidst *putrid animal matters* seem more liable to plague and typhoid fevers than most other classes.

18. Artizans exposed to inhale *minute particles of dust* are very liable to pectoral diseases. This is especially the case with knife and needle grinders. They are subject to the disease called *grinder's rot*, an incurable consumption, which renders this occupation most deadly. Currents of air, and interposed plates of glass, have been used to remedy this evil. Large magnets have been employed to arrest the iron dust, but it cannot abate that from the grindstone itself, which is not less fatal.

19. *Workers in lead, brass, and copper,* are subject to disease, from those substances finding their way into the system, as already stated.

20. *Bleachers and Dyers* are liable to suffer from acrid fumes, in some instances, and also from sudden changes of temperature.

21. *Snuffmakers and Millers* are exposed to dust; and the former to the consequences of inhaling also a narcotic; but the effect is seldom very marked on either.

22. *Chimney-Sweepers* are liable to consumption, and to a peculiar cutaneous disease, the *chimney-sweeper's cancer,* which chiefly affects the scrotum. Early excision removes it; but it is liable to recur.

23. *Cotton, silk, and flax spinning* by machinery expose the operatives to bad air, dust, and confinement in hot rooms. This is especially injurious to the young, who are much employed, from eight years and upwards, in such manufactories. The hours of work of all classes in them are too long. Woollen factories seem to be less unhealthy on the whole; but in them the employment of very young children, and too long hours of labour, are to be regretted.

24. *Persons exposed to a high temperature,* such as *Cooks, Confectioners, Bakers,* are liable to rheumatism, from sudden changes of temperature. Bakers were remarked to be the most general victims of the plague at Marseilles in the beginning of the last century. *Sugar-refiners* are exposed to much heat, and to sudden chills. *Smelters of iron* and other ores are subject to the same; to cough, from dust, especially if they be founders; and their eyes become weak, from the intense glare of the metal. *Glass-blowers* not only suffer from these causes, but also from the excessive exertions of their lungs, which often give rise to hæmoptysis and asthma.

SECTION II.—CIRCUMSTANCES AFFECTING THE HEALTH OF COMMUNITIES.

Climate.

I. CLIMATE.—The effect of climate, the most general of these circumstances, depends chiefly on the temperature, the hygrometric state of the air, and the general force and direction of the winds. The temperature of any place is well known to depend, in a great degree, on its latitude. The inclination of the earth's axis to the plane of its orbit has diffused the influence of the sun's rays more extensively over the surface than if the same points had always a vertical sun. The changes in temperature had been marked long before there was an instrument for measuring their extent, and hence the distribution of the earth's surface into parallel zones denominated *climates;* but the invention of the thermometer showed how ill this arrangement accorded with observation; and it was soon found that there were very different climates under the same parallels. The average or mean temperature is obtained by a series of thermometrical observations, carried on in the open air and in the shade. Large springs and deep caverns usually have the mean temperature of the place where they occur; and it has been found that a series of observations made every hour through April will give a pretty accurate mean temperature of that place for the whole year.

Temperature, however, is also considerably modified by longitude. Thus it is found that the mean temperature of any latitude in Western Europe is higher than that of the corresponding latitude in Eastern Asia, or in America, as may be seen by casting the eye over Humboldt's chart of isothermal lines. A comparison of similar observations indicated to Sir David Brewster that there were in each continent certain meridians on which the mean temperature is the lowest in that parallel. These he termed the *cold meridians,* in approaching to which the mean temperature falls on either hand.

But the principal circumstance which modifies the effect of latitude is elevation above the sea. As we ascend mountains, the temperature falls; and in every region, if its mountains be sufficiently lofty, they are the abodes of perpetual congelation. The limit varies with the latitude: it is highest under the equator, and diminishes as we approach the poles: thus, at the equator, the point of perpetual congelation is more than 15,000 feet above the sea; in Britain it is about 5000. The climate of a place, then, varies with the latitude, with the longitude, and with the elevation.

Even when the mean temperature is the same, places may differ greatly in the extremes of heat and cold in summer and in winter. The chief agent in equalizing heat is the ocean, the temperature of the mass of which remains nearly the same in all latitudes. This renders the summers of islands less hot, and their winters less cold, than that of continents under the same parallels. The peculiarities of climate affect the vegetable productions of a country, and its salubrity is greatly modified by the nature of its surface. A region shrouded in forests is generally colder than one exposed to the rays of the sun; and the exhalations from swamps and marshes materially affect its fitness as a residence for man. Such countries are subject to violent intermittent and remittent fevers, especially when the marshes are acted on by intense solar heat; and in tropical regions such places are pestilential. Several other diseases appear to depend on climate, as the *goitres* and *cretinism* of the Alps and other mountainous countries, the *elephantiasis* of Africa and the West Indies, and the strumous affections of cold climates.

All these peculiarities must be considered by those consulted on.

The sites of towns.

II. THE SITES FOR TOWNS AND HABITATIONS.—If the medical man be asked to give an opinion on any particular site, let him consider—

1. *The Purity and Hygrometric state of the Air.*—The average proportions of the cognisable ingredients of atmospheric air are,—

	Measure.	Weight.
Nitrogene	77·50	75·55
Oxygene	20·00	23·32
Carbonic acid	0·08	0·10
Aqueous vapour	1·42	1·03

The proportions of the gaseous ingredients are nearly the same everywhere; but the proportion of aqueous vapour varies greatly, according to the temperature and pressure of the atmosphere. It is the source of clouds, dew, fog, and rain, according to the suddenness of its precipitation. The quantity present in air may be estimated by Leslie's *hygrometer.* The quantity of rain which falls in any place should be ascertained by the *rain guage*; and the quickness of evaporation by experiment, or by observations with Leslie's *atmometer.* The number of rainy days should also be noted; for the quantity of rain is not proportional to the number of wet days. In hot climates it rains more seldom, but more falls than in temperate regions. Thus, the mean annual rain in the West Indies averages 120 inches; at Calcutta it is = 81; at Rome = 39; at Liverpool = 33; at Edinburgh = 24; at Petersburg = 16. In any climate, more rain falls in mountainous districts than in plains. Thus, 50 inches fall in Argyllshire; whilst at Glasgow the rain is about = 30; at Elgin = 24 inches.

The changes in barometric pressure should also be noted. These are extremely small within the tropics, or even in Southern Europe, but fluctuate in Northern Europe, even to $\frac{1}{10}$th of the whole column.

2. *A Supply of potable Water* is a most essential requisite. It should not be *hard,* it should be free of any peculiar taste or smell; and the nearer its specific gravity approaches 10002, to distilled water as 10000, so much the better.

Medical Police.

The capability of carrying water through pipes, to any station, is important, when a colony is to be founded. Running water of a good quality is also very important; but it should be recollected that stagnant water is not wholesome.

3. *Fuel* is another essential requisite, both for cooking and for warmth. A plentiful supply of wood, coal, or peat is indispensable where many human beings are to be congregated. Open fire places are cheerful, but not economical modes of warming apartments; stoves are more frugal; hot-air flues combine ventilation with warmth, but require considerable attention in their management; steam-tubes convey an equable temperature, but are less convenient than the circulation of hot water, in the apparatus devised by Mr Perkins.

4. *Vicinity of Trees* is an important circumstance; but it must not be forgotten that a station buried in deep forests is seldom wholesome, and in hot climates is often pestilential.

5. *Vicinity of Hills and Mountains* is also deserving of consideration. If they be very lofty, in hot climates, the plains at their feet are often pestilential, producing *black vomit* and *jungle fever;* yet removal to the mountains immediately relieves the sufferer, as is witnessed in the ascent from Vera Cruz to Xalapa, and from Southern Hindustan to the Neilgherries.

6. *Vicinity of Marshes*, in every country, is to be shunned in fixing on a site for human habitations. Marshes produce malignant remittents in hot seasons, and give rise to severe hepatic disease. The marsh fevers of Walchern, and the *malaria* of Italy, originate in stagnant water; and the fatality of some of our stations in the West and East Indies are to be attributed to swamps. Some of them, as British Guiana, have become more healthy as the country is more drained and cultivated.

7. *Vicinity of the Sea* is always an important element in choosing a station. In hot climates the sea-breeze mitigates the heat of day, and renders it endurable. This breeze in summer is very regular, even at Gibraltar. The vicinity of the sea also mitigates the cold of winter. Sometimes it renders a station unhealthy, when the recession of the tide exposes a great extent of a muddy beach. This is especially the case at the mouths of great rivers; yet such stations, though unwholesome, are often politically important as naval stations, or as keys to the back country. Marshes into which sea-water occasionally enters are observed to be more pestilential than mere fresh-water swamps.

Drains and sewers.

III. Drains and Sewers are important public works, on the proper construction of which the salubrity of a station may greatly depend. They should have such a fall as to carry off impurities, and to prevent an accumulation of stagnant water. The Greeks and Romans excelled in their attention to such works; but the unhealthiness of many places in Italy, in the present day, is owing to the neglect of those useful structures. Egg-shaped drains are the best.

Public ways.

IV. Paving of Streets, and Care of Public Ways, are objects also worthy of the attention of the medical man, though chiefly in the province of the civil engineer.

Cemeteries.

V. Cemeteries.—Little attention has been, in this part of Europe, bestowed on the police of repositories for the dead. Burial in churchyards, in the midst of a crowded population, and even within churches, is still suffered to disgrace our cities. The French have set a good example; and the Turks have been long noted for the decent propriety and judicious position of their cemeteries, which are always beyond their towns. The same is the practice of the Chinese, and of many nations whom we call barbarous. A better system has commenced among us, in the new cemeteries of Glasgow, Liverpool, Newcastle, Edinburgh, and London; and it is fervently to be hoped, that ere long our towns will cease to be infected with putrid emanations from crowded churchyards, and the temple of God to be polluted with the frail remains of mortality. The cemeteries in London are a disgrace to the metropolis; but the new cemeteries are at a good distance from the metropolis, and are remarkable for their elegance and appropriateness, especially those of Norwood and Kensal Green; while those on each side of Edinburgh are distinguished by their propriety and neatness. The best mode of sepulture is probably in the earth, without vaults; but anything is preferable to the horrid practice in Rome, of disposing of the carcases of the poor in huge caverns, often opening into the very churches.

Hospitals.

VI. Hospitals.—The erection of hospitals is intimately connected with the subject of medical police. We cannot enter on a consideration of each sort of hospital, but state in general terms, that the wards should be lofty, with windows on one side, and galleries on the other for exercise to convalescents. Ventilation should be secured by some of the means already indicated; the wards should be provided with privies, and baths appropriated to each; the bedsteads should be of iron, as less liable to harbour vermin; airing grounds and convalescent rooms should be attached to all hospitals. In a lunatic asylum, each class of patients should have separate airing grounds; and occupations suited to their cases should be provided for convalescents. Foundling hospitals, from the mortality in them, even under the best management, seem to be amongst the most pestilent institutions of mistaken benevolence. Such considerations induced a German author to propose as an appropriate inscription over the gates of such establishments, "Children murdered here at the public expense." Hospitals for the sick, military hospitals, and barracks, all may fall under medical police.

Schools.

VII. Schools.—Seminaries for the instruction of youth merit more attention from the legislature than they have received. The rooms are often defective in ventilation; and the modes of warming them in cold weather are often very inefficient. In some schools too little attention is paid to vary the diet of children; and though seldom deficient in quantity, at large public and private schools, there often exists inattention to render it palatable, or to suit it to peculiarities of constitution. In many schools the hours of study, for very young children, are too long. The degrading practice of public flogging, even almost to manhood, in some schools, is brutalizing to the inflictor, and destructive of the delicate sensibilities of ingenuous youth. We must also stamp with our strongest disapprobation the practice of *fagging*, which prevails at some English schools, and is calculated to foster the vices of both tyrants and slaves. In female seminaries the lessons are generally too long, the pupils too sedentary, too little in the open air; and many female *accomplishments*, as they are termed, are apt to produce lateral curvature of the spine, as was fully proved by the late Mr Shaw.

Prisons.

VIII. Prisons.—The state of our prisons is much improved since the time of Howard. The principal improvements are in the county prisons of England, in many of which much attention is paid to preserving the health of prisoners, by clean rooms, commodious airing-grounds, and humane regard to their diet, and the cleanliness of their persons. In most of the prisons of this country, however, much is still defective, in what relates to the classification of prisoners, and separating juvenile delinquents from hardened offenders. In the county jails of Lancashire and Cheshire much has been done to render prisons what they ought to be; but even in some of the best English prisons there are still no hospitals for the sick inmates; and the jails of Scotland are far behind those of the two counties alluded to in every respect. As far as lodging and diet go, there is no room for improvement in many British jails; and this humane attention is rewarded by the disappearance of jail-fever from our island. The subject of prison discipline is a wide field. The benevolent exertions of the late Mrs Fry and her Quaker associates prove that much good would flow from attention to the instruction and moral improvement of the unhappy inmates of our prisons.

Lazarettos.

IX. Lazarettos and Quarantine Establishments are of Italian origin, at the period when the commerce of the East was engrossed by the free cities of Italy. The doctrine of contagion is not of modern origin, as has been ignorantly alleged. Notwithstanding the clamour of interested individuals a few years ago, no rational medical man denies the contagious nature of the plague; and we have no doubt that the immunity of this island from that dreadful scourge for 170 years, notwithstanding our multiplied relations with the East, is mainly owing to the rigour with which the quarantine laws have been enforced. Some of these regulations may err on the side of excess of caution; but this is far preferable to rash experiments, prompted by crude medical speculations, and supported, as they were attempted to be, by distortion of facts. The quarantine laws were revised in 1825, and the code is now, upon the whole, good. The quarantine stations for Britain are Standgate Creek, Deal, Milford Haven, Liverpool, Holyloch in the Clyde, and Inverkeithing Bay in the Forth.

Punishments.

X. Punishments.—This subject, the last of the present dissertation, is worthy of the attention of the legislator and of the medical jurist.

1. *Corporal Punishments*, inflicted by sentences of our courts, extend to imprisonment, whipping, and forced labour.

Imprisonment is adjudged for several offences, and even for inability to pay a debt. When the health of a prisoner might suffer from confinement in a damp or unwholesome jail, the humanity of judges has frequently mitigated the severity of the sentence, on the representations of medical witnesses. It would be unjust to inflict a greater punishment than the law contemplated, by the mode of confinement; but in general our jails are far more comfortable as far as lodging and diet are concerned, than the usual habitations of the very poor; and therefore imprisonment, in some instances, may have lost some of its salutary terrors in preventing crime.

Whipping is sometimes inflicted by sentence of the court, either publicly or privately; it is now generally applied to juvenile offenders in prison, and is far less frequently inflicted in public than formerly, especially since the abolition of the pillory for ordinary crimes. Flogging is still permitted to a limited extent both in our army and the navy. A medical man is always by on such occasions; and should he declare the punishment *enough*, even one lash more at that time inflicted is a crime, and would subject the officer who ordered it to indictment for murder, should the sufferer die. *Hard labour* is now generally inflicted by the *tread-mill*, a contrivance by which the united weight of the prisoners condemned to it puts in motion a wheel, which moves machinery. The defect of this punishment is its inequality. To active persons, accustomed to walking, it is a light exercise; but to sedentary persons it is a most grievous punishment, giving intolerable pain to the muscles of the legs and the spine. To the disgrace of our country it has been inflicted on females. Their muscles are too weak, and their habits little inured to such labour; and it is liable to induce *prolapsus uteri*, or miscarriage, if the prisoner be pregnant; or serious diseases of the female system, in various ailments of the sex. It arms, too, with a dangerous and tyrannical power ignorant justices and unfeeling magistrates. The law should forbid this infliction on females in all cases, and prevent the erection of tread-mills in all prisons not liable to the legal inspection of grand juries, which it seems *houses of correction* in England are not, they being "not under the jurisdiction of the sheriff of a county." The beating of hemp was formerly with us the infliction for petty crimes; and in Holland it was rasping of dye-woods in the *Rasphaus*, which was always considered as a severe punishment. In America the penitentiary system of forced labour has been tried, and is still a subject of discussion. Solitary confinement has also been employed there, which some have considered worse than death.

2. *Capital Punishments.*—In this country, excepting in cases of nobles for treason, *hanging* is invariably the mode employed by law. This is with justice preferred to any other mode of public execution, as the evidence of those who have recovered after suspension renders it probable that the person suffers very little pain, from his becoming speedily insensible; and when the *drop* is employed, the injury to the neck seems generally to extinguish life instantaneously.

Beheading is in this country performed with the axe, in Germany with the sword, and in France with the guillotine; the prototype of which seems to be the Scottish *maiden*, still to be seen in the Antiquarian Society's Museum in Edinburgh. The axe often requires a repetition of the blow, and the sword is liable to the same objection. The maiden chopped off the head by the descent of an axe loaded with lead. The guillotine slices it off, entering one side of the neck by an oblique edge. All sorts of beheading present a very ghastly spectacle, and habituate to the sight of human blood; besides which, serious doubts have been started as to the possibility of the head for a short time retaining its sensibility.

3. *Pleas in bar of Execution.*—When a person is condemned to die, execution of the sentence may be deferred on three pleas.

Insanity may be pleaded by the relatives of the condemned, and a jury may be appointed to try the sanity or insanity of the prisoner.

The *youth* of the party is the second. There is no age fixed by British law at which the perpetrator may not be executed for heinous crimes. In 1629 a child between eight and nine years of age was executed in England for an atrocious murder; one of ten years was condemned in 1748 at York; and a boy of sixteen was executed in Edinburgh, in 1812, for a murder. Blackstone states the lowest degree of non-age, by the practice of the English courts, to be seven years.

Pregnancy is the last plea admitted in our courts. When this is alleged, a jury of matrons is appointed by the judge to inspect the party, and if the allegation be found true, she is respited till after delivery. These persons are very incompetent to so delicate a task. It should be intrusted to accoucheurs, who, from the appearance of the mammæ, and the application of the stethoscope to the abdomen in the latter months, will readily ascertain the truth or falsehood of the allegation.

(T. S. T.)

MEDICI, Family of, celebrated in the history of Florence and Tuscany during the fifteenth century, was one which, by its extraordinary industry and activity at a time when the Florentines extended their commerce over the known world, rose to be one of the first in the republic. This opulence secured to its members so great an influence in public affairs, that they became the most powerful and the most highly respected of the many citizens whose public virtues were such as free and popular governments alone can develop. It was through the sincere attachment of their ancestors to the more democratic party of the democratic republic of Florence, that the House of Medici, in after generations, acquired its extraordinary popularity. The origin of its influence may be traced to Giovanni de'

Medici, who in 1342 was in the service of Gauthier de Brienne, Duke of Athens, and tyrant of Florence. Gauthier having been chiefly indebted to him for the power he enjoyed, resolved to get rid of this obligation. Accordingly, under pretext that Giovanni had not with sufficient vigour defended Lucca against the Pisans, he caused him to be put to death. The Medici swore to be avenged, sided with the people, and by their powerful influence were chiefly instrumental in freeing their country from that tyrant. Soon after this the nobility, who had for fifty years been excluded from all share in public affairs, attempted to regain their ancient authority, but found a powerful opponent in Alamanno de' Medici, the head of the family, who called the people to arms, and finally expelled the nobles. Some time after, when the two factions of the Ricci and the Albizzi were struggling for power, this house, though not so strong, remained faithful to the people; and in 1360 Bartomoleo de' Medici, son of Alamanno, conspired against the Albizzi, who were at the head of the government. The conspiracy was discovered; but he escaped capital punishment through the protection of his brother Silvestro de' Medici, a man high in office and greatly esteemed. Silvestro further increased his popularity in 1378, when, having been appointed gonfalonière of justice, he thought it necessary, for the liberty of his country, to lower the authority of the Albizzi, and to raise the democratic party. After Silvestro's death, the aristocratic Albizzi having attempted to regain the power they had lost, the people revolted; and in 1393 chose Veri de' Medici, son of Silvestro, as their chief. This good citizen, however, instead of making himself master of the republic, as he could easily have done, modestly used his influence to calm the agitation and restore peace and unanimity. But the nobility did not fulfil their promises, and fearing the popularity of the Medici, banished the family of Silvestro from the republic. In 1397 one of them, Antonio de' Medici, having tried to get back to Florence, fell into the hands of his enemies, and was forthwith executed. Several conspiracies were attempted up to the year 1440, which effected nothing but the destruction of the more influential members of the family. The few who now remained in Florence were too insignificant to be suspected or feared. One of them, Giovanni de Bicci de' Medici, born 1360, belonged to a branch of the family that, either from want of genius, or from poverty, had never been distinguished in public life. Giovanni passed his youth in obscurity, became a small merchant, rose to be a third-class banker, and by constant application and prudent economy gradually improved his fortune. Having visited Bâle and Constance, where the famous councils were being held, he took advantage of the high rate of exchange, and greatly increased his wealth. On his return to Florence, where his name was dear to a people who still held Silvestro and Veri in grateful remembrance, Giovanni was regarded by all, from his wealth and wisdom, as well as from his firm traditional attachment to pure democracy, as the only man in the entire republic capable of putting an effective check upon the growing influence of the oligarchy. The Albizzi, still in power, reluctantly yielding to the popular feeling, accepted Giovanni as one of the priors of Florence in 1402, 1408, 1411. This new position in public life gradually restored the declining influence of the family of the Medici. Giovanni went as ambassador to Naples in 1406, was governor (*podestà*) of Pistoja in 1407, and was sent ambassador to Pope Alexander V. in 1409 to congratulate him on his elevation to the papal chair. In 1412 he went to the congress of Pietrasanta to settle the dispute with the Genoese, who would not suffer Portovenere to be given to the Florentines. In 1420 he was one of the deputies appointed to accompany to the confines of the state Martin V., who had just been elected at the council of Constance; and finally, in 1421, he became gonfalonière, and one of the ten who had to direct the war against Milan in 1423. He died in 1429, at the age of sixty-nine. From this Giovanni de Bicci descended that double line of the Medici who, till a very recent period, ruled over Florence and Tuscany. He left two sons, Cosmo and Lorenzo, the former of whom may be considered as the founder of the family's greatness. Cosmo de' Medici, born in 1389, and elected one of the priors of Florence in 1416, became at the death of his father leader of the Medicean party. A banker, like his ancestors, he followed their example in liberality and splendour. In his palace, one of the finest in the world, he assembled the artistic, the literary, the learned, and the scientific men of Italy. The Greeks who had left the fallen empire of Byzantium sought refuge under his hospitable roof, and found in him a generous patron. He collected ancient books and works of art from all parts, and greatly contributed to the revival of learning in Europe. Knowing that patronage is more indispensable for the progress of the fine arts than for that of literature, he rewarded artistic genius with the utmost munificence. He distributed his bounty with an unsparing hand, often advanced money without security, and when he knew his claim might be disputed, he did not ask for a return. By these means he gained immense popularity, and was enabled to become a formidable opponent to Rinaldo degli Albizzi, at that time head of the Florentine republic. Rinaldo thought it necessary for his own safety to get rid of him; and having in 1433 succeeded in obtaining as magistrates of the *Signoria* men who were of his party, he summoned Cosmo to the palace, and, among other things, accused him of having caused the failure of the war against Lucca. The sentence of death was about to be pronounced, when the gonfalonière, Bernardo Guadagni, bribed by Cosmo's friends, proposed that he and all his partizans should be exiled.

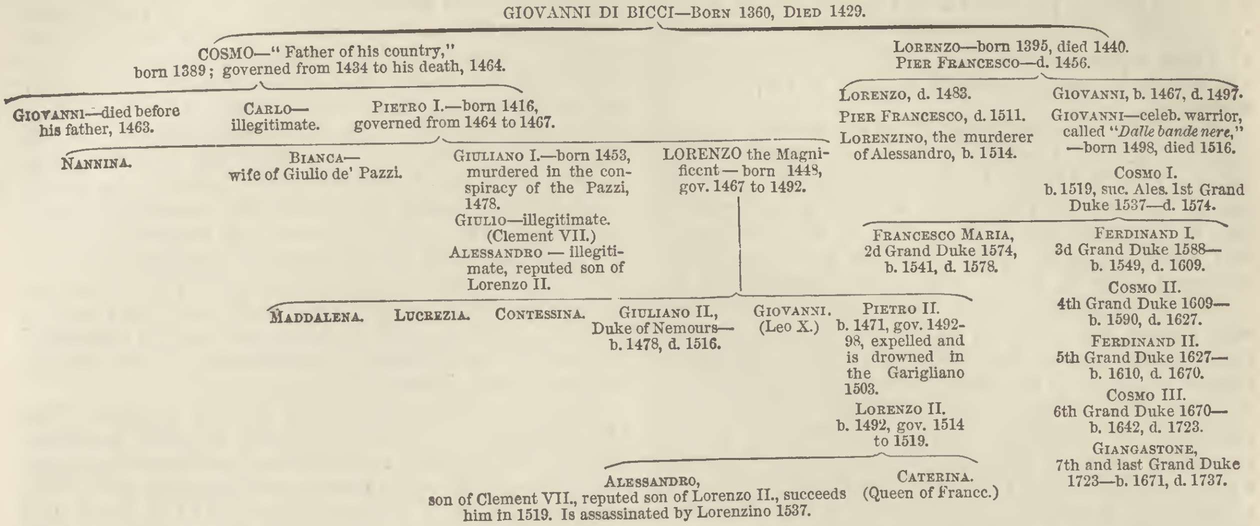
Cosmo retired to Venice, the ancient ally of Florence, and there, living in splendid exile, he built new palaces, gathered around him artists from all parts, collected books and manuscripts, employed learned men to correct them, and kept up a more active correspondence than ever with his friends and partizans both in and out of Florence. A year had scarcely passed, when, despite the exclusion of Cosmo's known friends from the ballot, the people elected a body of magistrates, or *Signoria*, less hostile to his family, by whom he was desired to return. Thus formally recalled, he triumphantly entered his native town, was enthusiastically received by the democratic party, and in 1434 intrusted by the priors to reorganize the state; while Rinaldo degli Albizzi and his friends were driven into exile. "This was a revolution," says Sismondi, "without bloodshed, but a revolution which laid the foundation of the Medicean tyranny, and sealed the death-warrant of the republic." After having ruled Florence for thirty years, he died in 1464, bequeathing his power to his eldest son Pietro. Cosmo was called by public decree the "Father of his country." His chief object, before his exile, was so to centre all the interests of Florence in himself, that he might become the soul of the political, monetary, commercial, artistic, literary, and scientific activity of his country. On his return, having defeated all rival factions, and assumed the supreme power, he thought Florence would never be tranquil, or maintain her ascendancy, so long as internal factions leagued themselves with neighbouring hostile potentates, who made party struggles subservient to their policy of repressing the Tuscan republic. The project he then formed of restraining the mutual jealousies of the Italian states by bringing them to a better understanding of their common interests, of making Tuscany the centre of a system of political equilibrium, or, in other words, making Florence the ruling power in Italy, while he himself was at head of affairs,—has been considered by some as Cosmo's principal title to political fame; while others more justly see in him the author of that centralization which, by destroying individual activity, prepared the way for the despotism of his descendants. He devoted himself very much to the study of Plato, whose philosophy he laboured to restore with all the energy he was accustomed to give to everything he undertook.

One of the most illustrious, if not the greatest member, of this family was LORENZO I., afterwards called the Magnificent, born in 1448 of Lucretia Tornabuoni and Pietro son of Cosmo. In 1467, when scarcely twenty years of age, he succeeded his father, a man of weak and irresolute character, who, during the short period of his government (1464 to 1467), had greatly impaired the popularity of the reigning family. Surrounded by false friends, who envied the greatness of the pretended democratic family, Pietro had not sufficient penetration to perceive his difficult situation, or the talent to make himself master of it. Seeing his patrimony had been greatly reduced by the prodigality of Cosmo, he, to regain wealth, and keep up the family influence, asked all the old debtors of Cosmo, which included a vast number of the people of Florence, to return the money which had been lent to them. Discontent, prosecution, conspiracy, and bloodshed were the only result of this policy; and on the death of Pietro, Lorenzo became heir to an inheritance of discontent and disaffection, which, if not speedily put down, was likely to prove fatal to his rising ambition. Lorenzo set to work with all the energy of a youth of twenty. His experience of state affairs dated as far back as Cosmo's death in 1464, when, at the age of sixteen, he had been often called upon to take part in important affairs in place of his infirm father. His youth induced the true friends of the Medici to associate with him his younger brother Giuliano. Having enjoyed the advantage of a first-rate education in literature, science, and philosophy, they learned early to imitate the literary and artistic munificence of their grandfather as well as his political wisdom. No sooner, however, had the two young brothers been placed at the head of the government, than the famous conspiracy of the Pazzi broke out, by which Giuliano lost his life in the church of Santa Reparata; while Lorenzo, although wounded, succeeded in saving himself by taking shelter in the sacristy. The people, who loved the Medici, put all the conspirators to death on the spot; "and more than sixty persons," writes Machiavelli, "either real or suspected accomplices, were executed by the infuriated mob, among whom was Francis Salviati, Archbishop of Pisa." Pope Sixtus IV., who seems to have encouraged the murderous attempt, and who was as much the avowed friend of the conspirators as the enemy of the Medici, exasperated at the ill success of the plot, excommunicated Lorenzo and the Florentines, under pretext that they had hanged the archbishop in his episcopal robes, and detained the Cardinal Riario in prison. Spiritual arms having proved ineffectual, he had recourse to temporal means, and by persuasion, exhortation, and menaces, induced some of the Italian potentates to raise an army against the Medici. Ferdinand, King of Naples, having become the principal ally of the pope, Lorenzo turned to France and Lombardy, and urged them to join him against the pope. The disasters experienced by the republic during the first campaigns only added to the excitement of the Florentines, who aided Lorenzo with the utmost enthusiasm. The evil, however, became too evident. Italy was about to become a battlefield, and civil progress would have been suspended, commerce and industry destroyed, the fortunes of the rising family endangered, if not annihilated, had not Lorenzo resolved by a bold and unprecedented act to extinguish the spark before it should burst forth into a flame. Without giving previous intimation, he set forth alone for Naples, and trusting to the faith of a noble adversary, put himself in the hands of his enemies. He went to the palace of King Ferdinand, and pled his cause in person, showing that the condition of Italy and the disposition of her princes and people were equally adverse to a general war; while the advantages of peace were as great as they were honourable. The king, struck with the ardour, eloquence, and political wisdom of the youth, not only consented to make peace, but immediately framed a treaty of mutual friendship between the two states (1479). The pope, thus left alone, was obliged to yield. Lorenzo returned to Florence, where he was looked upon with that respect which is the sure reward of successful daring. The policy of Cosmo now began to triumph: the influence of the Medici extended beyond the walls of Florence; their reputation became Italian; their preponderance was felt throughout the whole peninsula; and by their means the republic of Florence served to maintain a political equilibrum among the Italian states. The dream of Cosmo was thus realized by Lorenzo.

He now turned his attention to the arts of peace. Italian literature, which had shone with so much splendour through the genius of Dante, Petrarca, and Boccaccio, during the thirteenth century, had suddenly fallen into mediocrity and contempt. The study of Greek and Latin, which had been revived by the large-minded Cosmo, had perhaps tended to this injurious result. The *lingua volgare* was not yet considered noble; and no philosopher or scientific man could write his works in his native tongue. The learned language of the time was Latin, and all literary men, inspired by the example of Cosmo, gave their serious attention to its revival. Lorenzo, however, with a truer perception of the changes demanded by the progress of modern society, restored the Italian language to honour, wrote poetry in it himself, and led the way for Poliziano and Pulci, poets that will be read as long as the Italian language is known. He did not, however, neglect the classics; and he even vied with his grandfather in his zeal for collecting manuscripts and books; thus laying the foundation of the Laurentian Library, which, after all it has suffered from ruthless spoliation, is still the admiration of the world. Poliziano, in one of his letters, declares that Lorenzo used to say he would sell his furniture to buy new books, if he could not otherwise find means to do so. He sent Giovanni Lascaris, a learned Greek, twice to the East, at his own expense, to collect manuscripts. In addition to these services, this munificent patron of learning established schools in all parts of the Florentine republic, and founded the university of Pisa, from which were disseminated through Italy, and thence through the rest of Europe, that taste for art, science, and literature, which has done so much for modern European civilization. It was to him that Machiavelli dedicated his famous book *Il Principe*, and the celebrated secretary characterizes him as "eloquent and witty in discussion, wise in resolve, prompt and courageous in action." So great was the influence of Lorenzo's reputation, that he succeeded in causing his son Giovanni to be created cardinal at the age of thirteen, who became afterwards the celebrated Leo X.; and likewise put forward Giulio de' Medici, the illegitimate son of his unfortunate brother Giuliano, who became the no less celebrated Clement VII. Lorenzo died in 1492, at the age of fourty-four.

From Cosmo issued in direct succession the Dukes of Florence until 1537, when the Duke Alexander having been assassinated by Lorenzino, a descendant of the younger branch, the authority passed to that branch in Cosmo, who was the first of that series of grand dukes who ruled till 1737.

The Medici first gained absolute preponderance over the Florentine republic by their wealth, their patriotism, and their attachment to the democratic party. When their power was consolidated they became aristocratic, and finally upheld their authority by despotism and tyranny. Their influence having become, with Cosmo, a definite power, their history belongs to that of Italy and Tuscany. The following is the genealogical table of the two branches of the Medici family who governed till its extinction in 1737:—


GIOVANNI DI BICCI—Born 1360, Died 1429.
COSMO—"Father of his country," born 1389; governed from 1434 to his death, 1464.
Lorenzo—born 1395, died 1440.
Pier Francesco—d. 1456.
Giovanni—died before his father, 1463.
Carlo—illegitimate.
Pietro I.—born 1416, governed from 1464 to 1467.
Lorenzo, d. 1483.
Pier Francesco, d. 1511.
Lorenzino, the murderer of Alessandro, b. 1514.
Giovanni, b. 1467, d. 1497.
Giovanni—celeb. warrior, called "Dalle bande nere," —born 1498, died 1516.
Cosmo I. b. 1519, suc. Ales. 1st Grand Duke 1537—d. 1574.
Nannina.
Bianca—wife of Giulio de' Pazzi.
Giuliano I.—born 1453, murdered in the conspiracy of the Pazzi, 1478.
Giulio—illegitimate. (Clement VII.)
Alessandro — illegitimate, reputed son of Lorenzo II.
LORENZO the Magnificent — born 1448, gov. 1467 to 1492.
Francesco Maria, 2d Grand Duke 1574, b. 1541, d. 1578.
Ferdinand I. 3d Grand Duke 1588—b. 1549, d. 1609.
Cosmo II. 4th Grand Duke 1609—b. 1590, d. 1627.
Ferdinand II. 5th Grand Duke 1627—b. 1610, d. 1670.
Cosmo III. 6th Grand Duke 1670—b. 1642, d. 1723.
Giangastone, 7th and last Grand Duke 1723—b. 1671, d. 1737.
Maddalena.
Lucrezia.
Contessina.
Giuliano II., Duke of Nemours—b. 1478, d. 1516.
Giovanni. (Leo X.)
Pietro II. b. 1471, gov. 1492-98, expelled and is drowned in the Garigliano 1503.
Lorenzo II. b. 1492, gov. 1514 to 1519.
Alessandro, son of Clement VII., reputed son of Lorenzo II., succeeds him in 1519. Is assassinated by Lorenzino 1537.
Caterina. (Queen of Francc.)

Among the numerous works referring to this subject the following are the more important:—Nestor, *Histoire des Hommes Illustres de la Maison de Medici*, Paris, 1564; Ruby's *Discours de la Maison de Medici de Florence*, Lyon, 1604; Strozzi, *Della Famiglia Medici*, 1618; Ammirato, *Ritratti d' Uomini Illustri di Casa Medici del Ramo de' Duchi di Firenze e Granduchi di Toscana*; D'Aulberoche, *Eloges de Princes de la Famille de Medici*, Paris, 1627; J. M. Bruti, *Florentinæ Historiæ*, libri viii., Lyon, 1562; Varillas, *Les Anecdotes de Florence, ou l'Histoire Secrete de la Maison de Medici*, Haye, 1687; Varchi, *Storia delle Rivoluzioni di Firenze sotto i Medici*, Cologne, 1792; Bianchini, *De' Granduchi di Toscano di Real Casa Medici protettori delle Lettere e delle Belle Arti Ragionamenti Storici*, Venezia, 1741; Boissat, *Le Brillant de la Reyne, ou la Vie des Hommes Illustres du nom de Medici*, 1646; Galluzzi, *Storia del Granducato di Toscana sotto i Medici*, Firenze, 1781; Tenhove's *Memoirs of the House of Medici*, translated from the French by Sir C. Clayton, Bath, 1797. For the Life of Cosmo the Ancient, see Rozzi Silvano, *Vita di Cosimo de' Medici il piu vecchio*, Firenze; Maffei (Timoteo) *In Magnificentiæ Cosmi Medicei detractores libellus*, ibid.; Fabroni, *Magni Cosimi Medicei Vita*, Pisis, 1789, the best work on the subject; Cavalcanti, *Del Carcere, dell' ingiusto esiglio, e del trionfat ritorno di Cosimo Padre della Patria*, an old MS., published by the Canon Moreni, Firenze, 1821. For the Life of Lorenzo, Roscoe's *Life of Lorenzo de' Medici*, 2 vols. 4to, 1796, and the Italian translation of Milan, with many additions and corrections. *The Life and Pontificate of Leo X.*, by Roscoe, contains one of the most interesting accounts of the revival of letters and of the progress of the fine arts in our language, and has added much to our accurate knowledge of that important historical epoch (4 vols. quarto). See also Litta, *Famiglie Celebri Italiane*, Milano, 1832-38. (E. F.)

MEDICINE.

INTRODUCTION.

We propose to abandon the plan hitherto followed in previous editions when treating of Medicine, and to consider it rather as a branch of politics and of political economy, of singular interest to the citizen and statesman, than as a mere matter of science and art. It has a large encyclopædic literature of its own, to which our restricted space would not allow us to do justice in any degree. We propose, therefore, to give a general summary of the development and present condition of medicine and of the medical profession, with a more especial reference to their social and political relations. To this end we have traced their advancement and progress from the earliest period concurrently with fundamental changes in creeds and governments, so as to show under what conditions of society they rose and fell, and what their future development may be. The review is necessarily very general.

The term Medicine.

The word "Medicine," in its narrowest sense, signifies anything taken or applied by a person suffering from disease, with a view to relief or cure. Thus used, it expresses the *means* available in the art of healing. In a wider and philosophical sense it signifies all the *knowledge* applicable to the exercise of the art. This knowledge constitutes the science of medicine. Medicine is a term, therefore, which has a very varied and comprehensive signification, and includes every branch of medical science and every division of medical art. Practical psychology, surgery, midwifery, and pharmacy, and medical chemistry, botany, and zoology, are consequently departments of practical medicine.

Physic includes surgery.

Medicine, in this comprehensive sense, is synonymous with the Theory and Practice of Physic. By the 32d Henry VIII., cap. 40, § iii., the members of the London College of Physicians had expressly reserved to them the right to practise surgery. It runs as follows:—"And forasmuch as the science of physick doth comprehend and contain the knowledge of surgery as a special member of the same; therefore be it enacted, that any of the said company of physicians, &c., may, from time to time, as well within this city of London as elsewhere within this realm, practise and exercise the said science of physick in all and every her members and parts," &c.

Medicine the science of human nature.

When we examine in detail what is the knowledge that is necessary to this end, we find that it is, in fact, nothing less than a knowledge of the nature of man, and of its relations to all nature around him. Hence *physics*, the old term for the science of nature, was formerly synonymous with medical science, and the *physician* was but another name for the medical practitioner. This grand old name for the students of the science of human nature is so comprehensive, and so clearly indicates the duties and privileges of him who has to apply that science to the welfare of man, that it is to be hoped it will not be permitted to pass out of use, but, on the contrary, the physician shall henceforth be, as his name implies, able and fit for the practice of medicine "in all and every her members and parts."

First principles of medicine.

The physician looks at the human body as an artificer would look at a complicated piece of machinery, the construction of which is unknown to him, but which he has to keep and maintain in good working order, and, if possible, to render more perfect. He studies the preservation of the vital machinery in health, the restoration of it to health when disordered, and the development of it to greater perfection. These constitute the three great branches of medicine,—the prevention of disease, the cure of disease, the improved condition of man. Every man desires to enjoy and continue in life. Now, life is the continuous co-operation of those various organs which make up the body, and is enjoyed when they work harmoniously together. When this harmonious co-operation is interrupted, disorder or disease arises, and the vital functions are performed with pain, or at least languidly, imperfectly, and uneasily. It is one of the primary conditions or laws of life that the organism shall aim at the maintenance of the healthy or harmonious working of these various machines. The fulfilment of this condition has been attributed to variously designated powers, as—the vital principle, the archæus, the soul, instinct, the *vis conservatrix naturæ*, and the like. It is a law of existence common to all organisms, whether animal or vegetable, and is fulfilled by them all with little or no knowledge of the end of the law, or of the means by which it is attained. An infinite number of processes are going on in man, in fulfilment of this law, of which he is even yet wholly ignorant; and it is only by the most assiduous observation of the order of succession of vital phenomena and of their relation to various organs, that he has been enabled to determine in any degree the extent to which this law of existence is operative, and to learn the conditions under which it is fulfilled. It is by no means necessary to man's existence, when in health, that he should even know that he has organs. He is so little cognisant of the working of the brain as the organ of the mind, that to this day the greater number of mankind are practically of opinion that the soul can and does act independently of any organ whatever. As to the heart, lungs, stomach, and other viscera, it is a sign of perfect health when the man knows nothing whatever sensationally of their existence, and when their functions are performed wholly without his cognisance or aid. But these various organs are apt to be thrown out of gear. Then sensations are felt other than those of health, and a fundamental law comes into operation, in virtue of which the organism works to the beneficial object of repairing the disorder, and so removing those sensations. This is but a modification of that law of life in virtue of which the healthy action is maintained. The fulfilment of this law has therefore been attributed to the same forces; that is to say, to nature, the vital principle, an archæus, a *vis medicatrix naturæ*, *vis conservatrix naturæ*, &c. Nature appears to be the best of these terms, inasmuch as it more simply than others expresses the general law itself, without particularly specializing a subordinate agent. Nature, then, may be said to indicate what is necessary to be done in cases of disorder in the working of the viscera. If the disorder arises from mechanical causes, then in the lower animals—and in man when ignorant of medicine—the natural instruments or weapons are used for medicinal purposes. Thus the dog licks a wound it has received; the man covers it with his hand, supports the wounded limb, and the like. This is natural or instinctive surgery. *Surgery*, as a branch of medicine, includes the treatment of all mechanical injuries, together with all strictly external diseases, and the use of all mechanical or instrumental means of cure. *Medicine*, in its restricted sense, excludes these external diseases and remedial agents; as distinguished from the surgeon, and as a specialist, the physician neither treats them nor applies the remedies. His sphere of study is the great group of internal diseases, and their cure by drugs, together with the general principles of medical art—a knowledge as necessary, indeed, to the surgeon as to the physician. When, then, the cause of the disorder is not external, but within the organism,—that is, either in the fluids or the tissues of the body,—an attempt is equally made by nature to remove it. Now, noxious agents are formed within the organism during the natural processes, but in the state of health they are eliminated as rapidly as they are formed, constituting the secretions. If they are not eliminated, but accumulate in the organism, they cause disorder and disease. Again, noxious agents may be received from without (such as poisons, irritants, &c.), and these will generally operate in like manner as the retained secretions. In either case nature seeks the restoration to health by attempts at elimination or removal. These are often of a painful character, as coughing, vomiting, purging, and similar processes. It was considerations like these that induced the most distinguished physicians the world has ever seen to look upon the phenomena of disease as results of the efforts of nature. *Νουσων φύσιες ἰητροι*, is the pithy remark of Hippocrates—"Our natures are the physicians of our diseases." Sydenham (often designated the modern Hippocrates) adopted and promulgated the same theory. It has also been made the basis of modern systems of practical medicine. Unfortunately, the theory is only true in part; it applies strictly to individuals passing from a state of health to a state of disease, and who are living under the natural conditions favourable to health and to the exercise of the restorative powers of nature. But civilized men are surrounded by circumstances adverse to healthy function or structure; are in a large proportion not strictly healthy; and are therefore in a condition of body unfavourable to the exercise of the natural restorative powers, so that these natural efforts at cure are usually more or less imperfect. Nor even in the healthy is it a process to be implicitly trusted, for in them a temporary functional disease of an important organ may embarrass the action of other organs, and lay the foundation of chronic disease; and thus, if not arrested at the outset, may render nature's efforts more or less incompetent to restore to health. Medicine, then, seeks to know the natural processes, or physiology, so as to determine when the aid of art may be limited, or when it may be fully used.

CHAPTER I.—ANCIENT MEDICINE.

SECTION I.—ORIGIN OF MEDICAL SCIENCE AND ART.

Instinctive Medicine.

Origin of medical art.

Instinctive Medicine.

A knowledge of the conditions of health and of the curative uses of drugs is instinctive. Both the dog and the cat take remedies when ill; the dog, in particular, selects a certain grass and eats it medicinally. In the Greek mythology we find that a shepherd (Melampus) discovered the use of white hellebore by noticing that his goats purged themselves by eating it. He applied it to the cure of the daughters of Prætus, who, having taken vows of celibacy, appear to have become hysterical and monomaniacal. Bees apparently display in their political arrangements a knowledge of the laws of health, or of public hygiene. They ventilate their hives by a process admirably adapted to the desired end; they inclose dead animals which they cannot remove from the hive in hermetically sealed coffins.

In man a simple reason takes the place of the instinct in the lower animals. Thus, if he is nauseated, he thinks he will be easier if he could vomit, and accordingly looks about for some means to fulfil his purpose. The historians of medicine have found it necessary to go back for its origin to a very early period in the history of mankind; but this seems hardly necessary to the philosophical inquirer, because modern society, and the most highly civilized races, present the science and art in every stage of development.

An unlettered peasantry, remote from towns, and without a resident clergyman or practitioner, exhibits the practice of the art in all its simplest and primary forms. The sick rely upon their own experience or upon that of their neighbour, of whom one may be more sagacious or more pretentious than the rest. To this experience are added traditional medical knowledge of unknown origin, a belief in occult and mysterious agencies for evil and for good, a superstitious dread and worship of those agencies, and therewith superstitious practices and remedies. The "wise man" of the Christian village is a witch-finder, a meteorologist knowing in storms and strange appearances, a herbalist, a cunning trader on the superstition and ignorance of the people, and not without power to compel obedience to his commands. Many such still exist in every part of civilized Europe, as they have existed everywhere from the remotest history of society.

Origin of Scientific Medicine, and of a Medical Profession.

Natural development of medicine.

The development of scientific medicine, and of a medical profession, always takes place through successive phases. The simplest form of medical art readily passes into the patriarchal, in which the head of the tribe or community is the healer of disease and the depositary of all power. To this, in a more developed state of society, succeeds the sacerdotal, in which the heads of the people bear predominantly a sacred character. Out of the sacerdotal body next arises a distinct professional body, separate from it, and therewith a distinct science of medicine; and then, as the latter is developed, antagonism and conflict takes place between them. Next society passes into the phase of high civilization, and finally falls under the power of the military hierarchy. Concurrently with this change, religion, civilization, science, and medicine decay, to rise again from a renovated society. We have glimpses of this succession of phases from an early period of history. The earliest historical development of scientific medicine is everywhere traced from a priesthood, and the development of a priesthood to that combination of mental qualities and duties exhibited in the village *magos*. The "medicine man" of the Indian tribes in North America indicates what must have been the germ of the great sacerdotal caste which ruled so long and so powerfully the great nations of the east. Politics and law, religion and science, and (in close connection with religion and science) medicine, both as a science and an art, were all in the hands of the priesthood. This is the stage in human society of sacerdotal predominance. To this union of the priest, lawgiver, and physician, we owe that remarkable remnant of medical science found in the Mosaic writings—the system of public and domestic hygiene established amongst the Hebrews on a religious basis, and manifesting a very practical knowledge of various diseases and their origin. Learned as Moses was in all the knowledge of the Egyptians, it is more than probable that his system, in all essential details, was a reflection of the Egyptian doctrines and polity. Seventeen hundred years before the birth of Christ, Joseph commanded "his servants, the physicians," to embalm his father; a command sufficiently indicative of chemical science. Recent researches into the natural history of parasitic animals—the *Entozoa*—have rendered it probable that the Mosaic laws regarding clean and unclean animals had a foundation in a knowledge of these organisms—their nature, habitats, and the diseases they induced. We also get glimpses of the medical knowledge of the Egyptians in the older Greek authors. In the fourth book of the *Odyssey*, mention is made of Jove-descended Helen putting into wine a drug "that frees men from grief and from anger, and causes oblivion of all ills." This and other excellent drugs were given to her by the wife of Thone, "an Egyptian; where the bounteous land produces very many drugs; many excellent when mingled, and many fatal; and each physician is skilled above all men."

Early Egyptian medicine.

The cultivation of science could only be carried on through records of observation and experience. It was amongst the priesthood that writing arose and was first practised. Medicine, as an important branch of natural science, was necessarily a constituent element of the hieroglyphical or sacred literature, and was studied by the priests and priest-kings with ardour and success. Samuel was the chief of a school of prophets or *magoi*-priests; Solomon, King of Israel, was a great botanist, zoologist, and pharmaceutist, as well as pontiff, ruler, legislator, and moral philosopher.

Origin of a Medical Profession and Medical Literature in Asia.

Early Asiatic medicine.

The Levites, or sacerdotal caste of the Hebrews, appear to have practised medicine exclusively in the earlier period of the Jewish nation. To what extent the books of Hermes are authentic and ancient admits of question; but there is no question that the sacerdotal or hierarchical division of the people into castes extended over the whole of Asia, as well as through Egypt, during the earliest periods of civilization, and that the study of philosophy and the practice of medicine passed into the hands of a subdivision of the priestly caste, and thus the profession arose. The *Ayur Veda* appears to be the most ancient of the Hindu sacerdotal medical writings. Its date has been fixed at not later than the fourteenth century before Christ—that is, 900 years anterior to Hippocrates; but it appears to have been nothing more than a summary or abridgment by professional writers of still more ancient medical doctrines and practice. It contained eight divisions. The first two were surgical, including obstetric surgery; the third contained general pathology and the practice of physic; the fourth, pyschological medicine, or the treatment of insanity, founded on the theory of demoniacal possession, so prevalent throughout the east amongst all nations; the fifth treated of the cure of infantile diseases or prædiatrics; the sixth was devoted to toxicology; the seventh to personal hygiene and metallurgical chemistry; and the eighth to the diseases of the generative functions. The medical caste (*Vaidya*) amongst the Hindus received their designation from this ancient work—the term meaning one who understands the *Vidya*,—*i.e.*, the *Ayur Veda*. Besides the matters detailed, this ancient Veda contained anatomy, systematic general pathology, materia medica, and therapeutic hygiene. The ancient Hindu philosophers who lived subsequently to this work were termed *Rishis;* they also appear to have been a distinct body or college of commentators on the *Ayur Veda*, and teachers of philosophy and medicine. The *Charaka*, an ancient Hindu cyclopædia of medicine, was written by one of them; it is in the form of a dialogue. Another ancient standard work of this kind is the *Sushruta*. It is also a commentary on the *Ayur Veda*, but treats more especially of surgery, in addition to other branches of medicine. The *Rishis* were peripatetic lecturers on medicine; they also travelled about, like the ambulant physicians of Greece, curing diseases, and illustrating the influence of customs, manners, climate, and the like, on health. Their pupils went with them and took notes of their lectures. Many of these, in the form of compilations, are still in existence.[1] Hindu medicine has been stationary or degenerate for a lengthened period. Its origin is wholly lost in a remote antiquity.

The Ayur Veda. 1400 B.C.

Hindu medical profession.

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[1] *Commentary on the Hindu system of Medicine*, by T. A. Wise, M.D., p. 12.

SECTION II.—ORIGIN AND DEVELOPMENT OF ANCIENT EUROPEAN MEDICINE.

European Medicine in Greece.

Ancient European medicine.

European medicine dates as to its literature from the time of Hippocrates. The Hippocratic writings constitute a very complete summary of medical doctrines and practice as they were taught in Greece about 500 years B.C. The origin of Greek medicine and medical literature is as mythical to us as the origin of the *Ayur Veda* is to the Hindus. The first founders of it are also equally mythological personages. Chiron evidently corresponded to the Brahmans and to the priests of Egypt in his knowledge, and to the ascetic *Rishis* of the Hindus in his life and conduct. The myth is, that he held a school of physics in a grotto in Thessaly, and taught philosophy, music (or the principles of art), astronomy, the military art, political science, and medicine. A majority of the Argonautic heroes, and of the commanders at the siege of Troy, are represented as having been his pupils. Hercules and Æsculapius are also mentioned amongst the number. It is probable that the name indicates an ancient learned class, or incorporated body of professional teachers, rather than an individual, and points especially to the science and practice of surgery; for Chiron was celebrated for his surgery, as were his pupils. Hermes, like Chiron, was a mythical personage; and the books which bore his name in ancient Egypt are believed to express nothing more than the literature of the sacerdotal or learned corporations of Egypt. Sanchoniathon, the name of another author of this class, it is said, is a Phœnician word which signified a *magus* (philosopher or priest). The Phœnician writings that go under that name date probably from the age of the *Ayur Veda*. Whatever Chiron may have been, his successor Æsculapius was certainly already a purely mythical person in the time of Plato, and probably for 800 years previously.

Sacerdotal stage of Greek medicine. 1200 B.C.

The sacerdotal period of Greek medicine commences in the twelfth century B.C. with the erection of a temple to Æsculapius, about fifty years after the Trojan war. These were shortly multiplied throughout the then civilized world, and the priests were designated Asclepiadæ, or descendants of Æsculapius. They were in all particulars a sacerdotal medical caste. Their method of treatment being carried on in the temples, comprised all the essential elements of modern systems of empirical medicine. They had hydropathic establishments situated at or near thermal springs or fountains of living water, or upon the sea-coast, or amidst beautiful mountain scenery. Diversion of the mind, exercise of the body, regulated diet and regimen, friction and inunction of the skin, sea-bathing, mineral baths, and waters,—these and similar agencies constituted their remedial means. Besides these, they acted upon the imaginations of their patients by nocturnal religious solemnities and illusions of an impressive character, performed within the sacred precincts of the temple. Modern mesmeric processes and false miracles are, in some of the details, analogous to these, and wholly so as to the general principle upon which the method of treatment is founded. These delusions of the imagination were made subjects of ridicule amongst the Greeks at a later period of national culture. Aristophanes, in one of his comedies, puts an absurd description of the whole affair into the mouth of one of the characters who had been a patient. "The priests of the temple of Æsculapius," he says, "after having extinguished all the lights, told us to go to sleep, adding, that if any one should hear a hissing, which indicated the arrival of the god, he should not move in the slightest manner. So we all laid down without making any noise; but I could not sleep, because the odour of an excellent broth that an old woman held near me agreeably excited my olfactories. Desiring most ardently to slide along to it, I raised my head very quietly, and saw the sacristan going the round of the altars, take away the figs and cakes from the sacred tables, and put into a sack everything that he could find. I believed that I had a right to follow his example, so I rose up to go to the old woman's pot."

Origin of a lay Greek profession, and stage of conflict with Sacerdotal power.

Origin of lay Greek profession. 500 B.C.

These temples of Æsculapius being hospitals, were also the medical schools of the time. History has preserved the memory of four of the most celebrated;—that of Rhodes was the most ancient, and was already extinct at the time of Hippocrates; that of Epidaurus was consulted by the Romans; the school of Cnidos originated a small treatise of practical aphorisms—the *Cnidian Sentences;* and that of Cos gave birth to Hippocrates. It was at this school that the greater number of the Hippocratic treatises were commenced, if not written, although some are doubtless of a subsequent period. The appearance of these treatises therefore indicates one of those epochs in science, like that of Sanchoniathon and the *Ayur Veda*, in which the accumulated knowledge of a people is re-cast and digested by professional men. It was the age of Pericles,—that age in which the Greeks attained to so high a position both in arts, war, and philosophy,—the age when Socrates brought moral philosophy so near to Christian truth, and when natural history, logic, and metaphysics received a definite culture. The whole period during which the Hippocratic writings appeared extends, in fact, from the time of Pythagoras, about 500 B.C., to the death of Aristotle, 322 B.C.

Greek science in conflict with sacerdotal power. 500–300 B.C.

This advance in Greek philosophy and science appears to be mainly due to Pythagoras in the first instance, who, having studied philosophy and medicine in the then existing schools of Egypt, Phœnicia, Chaldea, and India, returned with an ample knowledge of Hindu, Chaldean, and Egyptian science and philosophy. From the fragments that are left, we may conclude that the philosophy and system of teaching of the Brahmans was that which he adopted. His philosophical views as to the transmigration of souls, his novitiate, code of morals, rules of abstinence, temperance, and purity of person and conduct, are very similar. He also, like the ancient *Rishis*, travelled from town to town as a teacher or lecturer, and established communities, apparently of a monastic character, in the principal cities of Magna Græcia. Pythagoras seems to have been contemporary with Confucius, the great reformer of religion and morals amongst the Chinese, and to have closely resembled him in essential particulars. But Pythagoras and his followers were not so successful in politics as the Chinese reformers. So soon as they interfered with the established religion and governments, they became obnoxious to the priesthood and to the tyrants who governed through them; so that the Pythagorean communities were broken up, and not a few of the sect were driven into exile or put to death. The life, trial, and death of Socrates may be taken as an example and illustration of the conduct, moral philosophy, religion, and fate of the followers of Pythagoras. Science had departed from the priesthood, and was already in antagonism to it. The diviners, soothsayers, and augurs,—the pontiffs and priests, with their idols, temples, omens, and oracles, were but the participants or agents of the ruling power in the state. The natural science they possessed was mainly used as an instrument for deceiving the multitude in various ways, as by simulating the miraculous, imitating thunder and lightning, contriving the flight of birds on this side or on that—in the east or in the west. With these men the earnest seekers after truth, as well religious as physical, came necessarily into conflict; and we have enough of the history of those times remaining to judge of the result. The palmy days of the ancient Greek republics were analogous in this, as in other particulars, to the era

Analogy of ancient Greek and modern Italian States.

of the modern Italian republics. A degenerate priesthood, rich in temples and lands, and possessing the secret springs of political power, held an almost undisputed sway over the unlettered populace, just as in the period of the Reformation. Equally at both periods they had become the mere exponents of hero-worship, and reflected nothing better than the vices and superstitious traditions of a sensual and ignorant people. Votive tablets were hung up in the ancient temples by the populace, expressive of their gratitude to a deified hero for medical aid afforded, just as had been done for many centuries previously in Egypt and India, and just as has been done for many centuries past in Europe in the temples of a similarly degenerate Christian period. Strange it is to see a medical superstition like this maintaining its hold upon man, and encouraged by the priesthood, through a long succession of vicissitudes, from the earliest dawn of Babylonian and Egyptian history to the latest day of the nineteenth century. And when Galileo, like Pythagoras, developed a truer system of the universe, the dominant sacerdotal body repelled it as being fatally opposed to their traditions, and persecuted the author. We shall find that in successive eras of man's history a similar antagonism between philosophy and traditional theology,—between scientific truth and the corruptions of revealed truth,—was developed. Nay, it is far from improbable that now, in the nineteenth century, we are on the very verge of a similar conflict.

SECTION III.—RISE OF THE ALEXANDRIAN SCHOOL.

The Military Power predominant in Greece.—Decline of Greek Medical Culture.

Decline of Greek medical culture. B.C. 336.

The wars which filled up the life of Alexander, the conqueror of Greece and Asia, interrupted the progress of science and philosophy in Greece. With the loss of freedom national culture became debased, and science was trampled under the feet of a cruel military superstition. Hero-worship attained its highest development in the assumption of divinity by Alexander, who outraged science in the person of Callisthenes, his friend and fellow-student under Aristotle, and whom he put to a death of torture for refusing to fall prostrate before him. But after his death science soon reared its head again in Egypt, in that city to which Alexander had given his own name. Two of his lieutenants and successors (Eumenes and Ptolemy) became its firm friends, emancipated it from the control of a corrupt religion and an effete priesthood, and gave its cultivators protection and a home. Pergamos was already celebrated for its temple of Æsculapius, and as a school of medicine. Here Eumenes collected in a large library all the recorded knowledge of the times. It was from this school, more than four hundred years later, that Galen sprung.

Pergamos. 263 B.C.

Rise of the Alexandrian school. 332 B.C.

Ptolemy Lagos, the uterine brother of Alexander the Great, rivalled Eumenes in his endeavours to advance science and art. He had already interested himself in the philosophy of India, where he had witnessed the self-immolation of an Indian *magus*. When he ascended the Greek throne of Egypt, he endeavoured to systematize the vast erudition that had been accumulating for many centuries throughout the civilized world, to utilize it, and to advance all branches of knowledge. It was this spirit that produced the Septuagint. His son Ptolemy Philadelphus not only gathered together all the written science and literature within his reach, and so founded that great library of Alexandria which survived the political vicissitudes of more than nine centuries, but he also invited to, and encouraged learned men at Alexandria from every quarter of the world, irrespective of creed or race.

This era was another of those epochs at which the human mind stops to take an estimate of its knowledge, and to lay the foundation for a new superstructure. Medicine participated in the general impulse given to science; but its greatest advancement was due to the establishment of schools of practical anatomy, and the cultivation of natural history, the materia medica, and pharmacy. Alexandria became so distinguished as a school of medicine that, in the time of Galen (nearly five hundred years after its foundation) a physician had a certain reputation already simply from having studied there. Almost all the distinguished physicians of the time were from the school of Alexandria.

Herophilus. 285 B.C.

Herophilus was the principal connecting link between the Greek and Alexandrian schools. He was born at Chalcedon (not at Carthage, as some writers state), a small town in Bythinia, and studied medicine at Cos under Praxagoras, the last of the Asclepiadæ, and the successor to Hippocrates. Having completed his studies, he went to Alexandria, where he reduced the dislocated shoulder of Diodorus Siculus, one of the many learned men which Ptolemy Philadelphus had gathered around him. He was an attractive public teacher, and wrote a learned, complete, and highly-esteemed theory and practice of medicine, of which, unfortunately, only fragmentary notices and extracts remain. But his chief merit was his indefatigable anatomical and physiological researches. Aristotle had already prepared the way for a great advance in human anatomy and physiology by his investigations in comparative anatomy and physiology, of which he laid the foundations. Hence, when the Alexandrian school carried their inquiries into human anatomy and physiology by careful dissection and experiments, they had their labours rendered much easier by this important advance. So extensive and comprehensive were these researches, that Herophilus may be declared with entire justice to be the founder of scientific anatomy and physiology. To him is due the great discovery of the anatomy of the nervous system, and the fundamental principles of neurology. Plato and Aristotle hardly knew that there were nerves; Herophilus demonstrated the functions of both the motor and sensitive. The anatomy of the brain and spinal cord was also much advanced by him; and it is pleasant to know that his name still sounds in the ear of the medical student when the position of the *torcular Herophili* is demonstrated to him. He it was who fixed the seat of thought in the brain, and more especially in the fourth ventricle. Herophilus would have been more successful if he had been free from the trammels of philosophical and religious dogmas; for it is evident that, like many original investigators, he attempted to square his researches with the established creeds of the day. Thus, although he placed the seat of the intellect or of thought in the brain, he made it only one of four forces, the other three being seated in the liver (the nutrient), the heart (the preserving), and the nerves (the sentient or feeling). In this he followed Plato and Aristotle. His great practical contribution to science was an elaborate doctrine of the pulse, which seems to have become part of the Chinese system of medicine, and is still extant in China.

Erasistratus. 260 B.C.

Erasistratus was the contemporary of Herophilus, and, like him, was a light of the Alexandrian school. He was a practical anatomist, a skilful and bold surgeon, and a good physician. He was sparing in the use of the lancet or of powerful remedies, preferring abstinence and rest. He introduced chicory into practice for hepatic affections.

Serapion. 235 B.C.

Serapion, the head of the sect of empirical practitioners, was also of the Alexandrian school, and lived about fifty years after Herophilus and Erasistratus. To this sect belonged also Heraclides of Tarentum, who advanced general pathology and the practice of medicine, materia medica, pharmacy, and surgery. After his death toxicology had special attention. Mithridates, King of Pontus, has connected his name with a composition (a theriaca), which he prescribed as an antidote to poisons. The fact is a significant comment on the uses to which an improved knowledge of materia medica and pharmacy were then (as now) put. Elaborate pharmaceutical compounds characterized the second century before Christ. The *Theriaca* and *Alexipharmaca* of Nicander of Colophon, are two of the few works of this era which have come down to us. The formula for the Damocratic confection, invented by Damocrates, a contemporary of Nicander, contains forty-four ingredients. It was given in the Pharmacopœia of the College of Physicians of London, published in 1746, together with others of the same period. The Philenium (a sedative compound containing opium as the efficient ingredient) was one of these; it bore the name of Herennius Philo, a native of Tarsus, the metropolis of Cilicia.

State of medicine 321–100 B.C.

During the period intervening between the death of Alexander the Great and the first century before Christ, medicine had hardly taken root in Rome. It was studied principally in Greece, Asia Minor, Egypt, and Magna Græcia, or Southern Italy, where medical schools abounded. Some of the family of Herophilus appear to have founded a medical school at Laodicea, a city that at the time carried on a lucrative commerce, especially in wines, with Alexandria, and another at Smyrna. These seem to have been termed Herophilian.

We have nothing but fragments of the medical works which emanated from the Greek school of Alexandria prior to the Roman conquest. There is reason to think, however, that the prejudices of the people sooner or later threw obstacles in the way of the practical anatomist, and that thereupon succeeded a period of speculation and decline. This most probably began anteriorly to the Roman conquest and the burning of the great library by Julius Cæsar. Cleopatra undoubtedly carried out the philosophical traditions derived from her predecessors the Greek kings, and endeavoured to replace the loss of the library by substituting that of Pergamos, which she solicited as a gift from Mark Antony. The measure served to maintain the reputation of Alexandria as a great school of philosophy, medicine, and science generally; but the ancient religion was become effete; the Roman arms triumphed everywhere, and the metropolis of the world was next to become the centre of science as well as of government, to which the great Greek schools became merely tributaries.

SECTION IV.—ORIGIN AND DEVELOPMENT OF MEDICINE IN THE ROMAN EMPIRE.

The Patriarchal and Sacerdotal Stage of Roman Medicine.

Medicine in Rome—its patriarchal and sacerdotal stage. B.C. 750–200.

The Romans (if the early annals of the city may be trusted) were warlike agriculturists,—not civilized, yet not barbarous,—being in close intercourse with the cities of the great Etrurian confederacy, and of Magna Græcia, in which scientific culture and the arts attained to as high a development as in Greece itself. Medicine, nevertheless, passed through its successive stages of development in the Imperial city.

The Roman national mind, when fully developed, was essentially political and military; it had little sympathy for science or philosophy. The Roman people were content to be without native physicians for nearly five centuries after the foundation of the city. The elder Cato (about 200 B.C.) practised patriarchal medicine when the Greek schools were in their glory, and was himself the physician of both his household and his domestic animals. It is said, indeed, that his unskilful treatment proved fatal to his wife. Cabbage was one of his most reliable remedies; and the magical words he used for the reduction of luxations and fractures are still extant. With him this patriarchal medicine was a matter of principle, or perhaps more correctly, of pride and ignorance. He hated the medical profession. He pretended to believe that the Greeks had sworn among themselves to kill all barbarians (and to the Greeks the Romans were eminently of that class) by means of drugs. He was indignant at the imputation of barbarism. He was a type of a dominant but ignorant class still plentiful in the world. His haughty temper could not brook superior knowledge, or the claims to it. As he detested the people, so he detested the philosophers, rhetoricians, and physicians, of Greece; he accused them of corrupting the Roman people, and at last succeeded in obtaining a decree for their expulsion. Nevertheless the physicians were exempt. Two hundred and fifty years later Pliny exhibited similar national prejudices against Greek science and literature, although his *Materia Medica* was almost wholly copied from Greek writers. Like Cato, he denounced all foreign, that is Greek physicians.

It was when the increasingly numerous population of the city of Rome was seriously diminished by a pestilential disease, about 187 B.C., that the Romans first appear as showing an interest in medicine. On that occasion, in accordance with their superstitious prejudices, a deputation of six went in quest of advice to the great Æsculapian temple and medical school at Epidaurus, when (according to the legend) they appropriately received one of the sacred serpents to take home with them, that they might build a temple to the god where the animal chanced to go ashore. This temple was duly erected, but it does not seem to have secured the usual results, that is, the establishment of a college of sacerdotal physicians. Yet it is hardly probable that sacerdotal medicine was not practised. The Etrurians possessed a knowledge of the physical sciences, and were the engineers of the day; they were also the metallurgists, chemists, and manufacturers, and they supplied augurs and a knowledge of augury to the Romans. We may conclude, therefore, that from the Etrurians sacerdotal medicine was also introduced into Rome.

Origin of a Medical Profession and Medical Literature in Rome.

Roman medical profession and literature. B.C. 200.

When medicine became a separate profession in Rome, the members did not arise out of the sacerdotal class, as in Asia and Greece. The *Medici* of the Romans were at first chiefly, if not exclusively, slaves or freedmen, the prisoners of war captured in their campaigns against the nations of the then civilized world. The first purely professional man seems to have been a Greek named Archagathus, upon whom, according to Pliny, the senate conferred the freedom of the city, purchasing for him also a shop and surgery in the Acilian Causeway. In proportion as the Roman empire extended over the flourishing and refined cities of Sicily, Greece, Asia Minor, and Egypt, Rome became cosmopolitan, and consequently attracted to it from every quarter the ambitious intellects of the day. One of these was Asclepiades, a native of Prusa in Bythinia, who having studied at Alexandria and Athens, established himself as a teacher of rhetoric at Rome, about the year 90 B.C. The Greek language and literature were then cultivated by the Roman nobility and gentry, for it was the fashion amongst them to send their sons to study at the great seats of science in Greece. These, when they returned to Rome, welcomed Greek professional and literary men to their city, and to their personal friendship. Asclepiades had the honour of Cicero's intimacy, and of that of other illustrious men of the day. He abandoned rhetoric for the practice of medicine, and, like all characters of his stamp, not only opposed the doctrines of the medical schools as then taught, but set forth a medical philosophy of his own, which was wholly speculative. It was a sort of medical atomic hypothesis, founded on the philosophical systems of Democritus and Epicurus, then popular with the educated Romans. It is from him that the popular medical theories as to the "pores" of the body have descended. He designated the Hippocratic method of patient observation of nature as θανατου μελέτη, "a meditation on death." His medical theories led to a simple enough practice. He had his plans for closing, opening

Archagathus.

Asclepiades. 90 B.C.

and relaxing "the pores," so that the imprisoned molecules could escape freely or not. Fevers, inflammations, and other "sthenic" diseases were due to obstructions of the pores; dropsy and similar asthenic diseases were due to relaxation. He had a sort of homœopathic maxim that one fever would cure another. Wine he administered according to the same theories which were adopted by Brown of modern times; a man whose history closely resembled that of Asclepiades in several particulars. Asclepiades was also hydropathic; for he made large use of cold water, and was the inventor of the shower-bath—the *Balneum pensile.*

Themison, pupil of Asclepiades. 60 B.C.

Themison, his pupil and successor, came from Laodicea, where already there was an important medical school,—an offset of the Alexandrian. He favoured the sect of the Methodists—a term which, derived from this body, received a singular application to a religious sect in the United Kingdom, founded in the year 1739 by John Wesley, a great ecclesiastical reformer, and a fellow of Lincoln College, Oxford. John Wesley and his friends at Oxford divided the day and the week into periods, during which they occupied themselves exclusively with certain pursuits, literary, charitable, and religious. It was from the practice of this orderly routine of duties that they were termed Methodists by their fellow-students at Oxford, for that ancient medical sect adopted a similar routine of treatment of disease. It was comprised within what was termed a metasyncritic circle; during this period each day had its allotted diet, regimen, duties, the treatment in minute details being distributed over successive days in periods of three days, or ternaries. Juvenal, in one line of his first satire, has intimated what success Themison had. '*Quot Themison ægros autumno occiderat uno.*' Methodism was a simple system; was therefore easily acquired; and, like all such, soon became very popular, especially amongst the unlearned.

Thessalus. A.D. 55.

Thessalus, a native of Tralles in Asia Minor, succeeded Themison, and fitly flourished during the reign of Nero. He was a man of low origin, and of ignorance and audacity unparalleled in that age of charlatans. Pliny describes him as professing to make his pupils perfect in medicine in six months. By this means he attracted a multitude of students, chiefly from the lower classes, whom he took with him on his visits to his patients for half a year, and conferred upon them an authority to practise medicine.

Soranus.

Soranus, a native of Ephesus, but a student of Alexandria, seems to have settled in Rome with the object of succeeding to the practice of the Methodists. He was, however, a man of scientific culture. He studied anatomy, published a work on the reproductive organs of the female, wrote an interesting life of Hippocrates, and systematized the practice of medicine. His contemporary and co-sectarian, Cælius Aurelianus, a Numidian, wrote one of the best works of the day on the practice of medicine, embodying not only the doctrine of Soranus, but all the most approved doctrines of the time. With a return to scientific culture in the leaders, the sect of the Methodists disappeared.

Celsus.

Cornelius Aurelius Celsus appears to have been contemporary with Asclepiades and Themison, or else to have lived shortly after them. He wrote on military affairs, agriculture, and rhetoric, as well as on medicine; and was probably a practising physician at Rome. He may be taken as the type of the learned or scientific Roman, and was evidently an eclectic. His work on medicine takes almost equal rank, as a classical work, with the Hippocratic writings; or he may, perhaps, be more fitly compared to Aretæus of Cappadocia, the most elegant and finished of the Greek authors of that day; and also, like Celsus, an eclectic. Celsus recommends, for the cure of hydrophobia, that the patient should be plunged over head into water, kept there for a short time, and then raised for a brief period and dipped again, repeating, alternately, the submersion and withdrawal. This practice has been preserved in the United Kingdom as a popular remedy (*Vide* article JENNER, vol. xii., p. 720), and is a curious piece of folklore, evidently derived, like many similar theories and practices, from the literature of medicine.

Period of culmination of Medicine in the Roman Empire.

Galen. Culmination of Roman medicine. A.D. 165.

The eclectic sect of Rome had in Galen its most distinguished member. He was, in all respects, a representative man. At this period science had recovered from the depression which followed upon the subjugation of Asia Minor, Greece, and Egypt by the Romans; and during the subsequent two centuries had even made considerable advance. Pliny had laid the foundation of natural history; Dioscorides of materia medica and botany. All the Greek schools supplied an uninterrupted immigration of scientific men into Rome and into the large commercial cities of the empire. It was about A.D. 165, and in the thirty-fourth year of his age, that Galen went to Rome on the invitation of the Emperor Marcus Aurelius. He was born at Pergamus, and was the son of Nicon, a geometrician, who took the greatest pains with his education. He was carefully grounded at Pergamus in anatomy, and was instructed in pathology and therapeutics by two masters; the one Stratonicus, being of the Hippocratic school; the other, Æschrion, of the Empirical. After the death of his father he went to finish his medical education at the great school of Alexandria. Having mastered all the theories and knowledge of the times, he gave his talents, and much time and labour, to constructing a summary of them. His works are therefore very voluminous, and constitute a perfect encyclopædia of the medical science of the day. It is for this reason that they took rank with those of Hippocrates, and that they constituted, equally with the latter, the text-book and manual of medical literature, down to the revival of learning in the fifteenth century. The term Galenist is hardly yet extinct in some parts of Europe.

The era of Galen was the culminating point of Roman science and literature. Marcus Aurelius, his patron, knew well how to value scientific culture. He was a man descended from a long line of noble Roman ancestors, and traced his pedigree, by his father's side, to Numa the philosophic king. He had every advantage of parental example and education, and was of the sect of the Stoics. The most distinguished member of that sect was Epictetus —already a Christian in his life and moral philosophy. This man Aurelius took for his model When he travelled into Greece he patronized science and philosophy of every kind; and on one occasion, when at Athens, founded four professorships for Platonics, Stoics, Peripatetics, and Epicureans, together with one for Rhetoric. He forbade persecution for religious opinions, and granted toleration to the Christians. Never was there a fairer prospect for science, and especially for medicine, than during the era of Galen.

The Military Power Supreme, and Decay of Medicine in the West.

Its decline. A.D. 165 to 466.

Yet the works of Galen constituted the last production of ancient Roman medicine. Everywhere the empire was being spoiled by barbarian foes, and the civilization of Rome was about to experience that long eclipse which continued through the dark ages. Aurelius passed, in defence of the empire, from the Rhine to the Danube, from the Danube to the Euphrates. Insurrections occurred in all parts; the unity of the empire was at last only maintained by military force, and the military force reigned supreme, electing and deposing emperors at pleasure. The effects of this grand change were soon manifest. The military power hated science. Hardly had Galen died, when Caracalla, the parricide and fratricide, visiting Alexandria under the pretence of worshipping the god Serapis, gave up the city to indiscriminate plunder and massacre, deprived the professors, who were Aristotelians, of their chairs, and suppressed all public discussions. He avowed a hatred of Aristotle; forbade the teaching of his doctrines; burnt his works; and persecuted to death his disciples. Caracalla was a representative man. He typified the age—an age when emperors had divine honours,—the military hierarchy was predominant, and religion and literature were equally debased. From this period the decline of medical science in Western Europe was rapid and continuous, until the incessant irruptions of the uncivilized nations of the north, and the interminable wars which resulted, reduced society to its elements. Boethius, born about A.D. 470, was the last of the Roman era of science; he was the martyr of philosophy. Thenceforward there was no longer anything but a shadow of philosophy or medicine, and all that remained was gathered under the wing of the new sacerdotal power that had arisen on the old; and which alone was able to overawe the brute force of the barbarians, and maintain social order. The era of Gregory the Great witnessed their revival.

Boethius, the martyr of philosophy.

SECTION V.—MEDICINE IN THE GREEK EMPIRE.

Partial revival of Greek Medicine in the East.

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.D. 328.

Although medicine was all but extinct in the West, it survived in the East, which withstood longer the elements of social decay, and found a new starting point in the new metropolis of the empire, founded A.D. 328 by Constantine the Great. Greek medicine had never been defunct; it was only eclipsed by the cosmopolitan grandeur. All the cities of Greece proper, and the Greek colonies of Asia Minor, as well as Alexandria, cultivated every branch of science during the Roman dominion. Yet, when the centre of medicine thus returned to its cradle amongst the Greeks, a great change had come over its social relations. It was no longer in subjection to the Pagan mythology of ancient Greece. That was about to become extinct in a faith and a religion destined to be paramount, as it had been, over the civilized world. The change had proved fatal to society in the West; in the East the empire went through the process with less disaster. But the Greek empire, with all its schools, did little to advance medical science. The Christians objected to human dissection even more strongly than the Romans. Tertullian, partly a contemporary of Galen, but several years younger, vilified the memory of Herophilus, 500 years after his death, by designating him as "that physician, or rather butcher, who dissected 600 men in order to learn the structure of his frame; who hated man, in order to find out nature;" untruly adding that his victims "did not die a natural death, but expired amidst all the agonies to which the curiosity of the anatomist was pleased to subject them." Hence, when the Christians came to power, anatomical research was less than ever possible. The succeeding authors were, for the most part, mere copyists and commentators on Hippocrates and Galen. In the middle of the fourth century Oribasius flourished, who was one of this class. He also, like Galen, was born at Pergamus, was educated at Sardis, at the school of Zeno (who afterwards settled at Alexandria), and became attached to the court of Julian the Apostate, who repeatedly appointed him the Quæstor of Constantinople. He wrote seventy-two books, which, at the request of Julian, he abridged into one. He collates from several authors not noticed by Galen, so that his works constitute a valuable appendix to those of the latter. It is interesting to notice that, towards the close of the fourth century, a Phœnician bishop (Nemesius of Emessa) appears as a physiological writer. He closely verged, it is thought, upon the discovery of the circulation of the blood, but this is not well established.

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ius.
525.

Aëtius, the Christian, born at Amida, a city of Mesopotamia, on the Tigris, and who wrote about the beginning or middle of the sixth century, was a student of Alexandria. He summarized like Oribasius, and quoted also like him from authors not mentioned by preceding writers, and whose works are lost. He made a large collection of formulæ, including those of many secret remedies. His writings are more interpenetrated with Egyptian and Persian knowledge than those of Oribasius; and it was probably in consequence of his oriental birth and associations that he introduced into medicine the doctrine and use of spells, rites, and incantations, and which even then had begun to disfigure and corrupt Christianity. Alexander, the son of a physician of Tralles, a city of Lydia, was a contemporary of Aëtius, and also a Christian medical writer. He was a more original author than the latter, but, like him, was a believer in magic, charms, and incantations. He furnishes the only known instance of a medical writer who avowedly borrowed anything from Osthanes, one of the most ancient of the Persian magi.

Alexander of Tralles.

Procopius. A.D. 540.

Procopius, the historian, appears to have been a man learned in medicine, if not actually a physician. He mentions the names of several of his medical contemporaries, and records their services. He describes the plague of 543, which spread from Egypt over the known world, and carried off, at Constantinople, 10,000 persons daily when at its height. He uses terms of a scientific and technical character.

Culmination and Decline of Eastern Greek Medicine.

Culmination of Greek Medicine. Paulus Ægineta. A.D. 600–640.

Paul of Egina was the last of the more distinguished medical writers who lived during the palmy days of the Eastern or Byzantine empire. His birth is fixed sometime in the seventh century. He was a representative man, being a learned and practical physician, a voluminous commentator, and a skilful surgeon. He was a great compiler, adding from authors not quoted by his predecessors, as well as the original matter their own works contained. His works brought up the science of medicine to its latest development in the East, as Galen's had done in the West. Already while he wrote, the tempest which was to fall upon the empire with destructive force was gathering. Heraclius had to defend his empire on all sides; from the Longobards in Italy; from the *Arari*, who crossed the Danube, invaded Thrace, and marched upon Constantinople; and from the Persians, who advanced through Egypt and Syria, on the one hand, and Asia Minor on the other, as far as Chalcedon. In 622 he commenced his successful expedition against the latter, and in the same year Mohammed openly assumed the character of a legislator and a prophet. In 640 the Arabs under Amrou captured Alexandria. The schools of science and philosophy were broken up, the professors driven away, and the great library, as is stated by some, was burnt by order of Omar II. While the followers of Mohammed were wresting its fairest provinces from the Christian empire of the East, the Emperor Heraclius was engaged in a theological dispute with Pope John IV., who procured his doctrines to be formally condemned by a council.

Its decline.

The Greek empire was able to maintain itself at Constantinople against the Arabs; but it was mutilated, and became more and more degenerate, so that at the time when medicine was flourishing with the caliphs, in connection with political energy and vigour, it languished with the emperors, in association with religious and political decadence. Only one Greek name is prominently connected with the history of medicine from the century subsequent to the fall of Alexandria to the date of the capture of Constantinople. John, the son of Zacharia, lived at the close of the thirteenth or beginning of the fourteenth century, and was surnamed "Actuarius," an honorary title for the chief physician of the court. The religious bigotry and persecution which prevailed among the Greek Christians had at an earlier period the effect of exiling the best minds of the nation, and driving them for refuge to the colleges and

Actuarius. A.D. 1000.

universities of the politic caliphs. At a later period the ravages of the Turks drove them alike from the Moslem and Greek academies. Already, therefore, there were numerous literary Greek exiles in Italy and France, where they were cordially welcomed, when in the year 1453 the Turks having captured and pillaged Constantinople, a number of learned Greeks fled into Italy, taking with them all the literary treasures they could carry off. That event closed the era of the old Greek civilization and science, and at the same moment was the birth of modern and true European civilization, yet after a long period of gestation.

Extinction.
A.D. 1453.

SECTION VI.—MEDICINE UNDER THE ARABS.

Revival of Asiatic Medicine.

Arab medicine in Asia.
A.D. 622 to 1036.

The exodus from Alexandria carried the light of medical science back again into Greece, and Magna Græcia or Southern Italy. In the former its decline was delayed; in the latter, the school of Salerno was either founded, or materially strengthened, by the Alexandrian refugees, and the foundation laid for the revival of letters in Europe, under Charlemagne. Later on, when the Turks took Constantinople, and the last remains of Greek science were finally stamped out, Italy was in like manner benefited by the irruption of barbarians, and became the source of light to Europe. But the central seat of medical culture was now transferred to Asia, and once again medicine was developed by an Asiatic priesthood. No sooner had the conquering caliphs consolidated their government, than they encouraged the arts and literature with the same enlightened zeal and success as the Ptolemies. Science was again cultivated over a wide extent of territory, extending from the Indus to the Tagus. It is more than probable, indeed, that medicine and philosophy were taught in very remote regions of Asia; and even flourishing medical schools existed in India and Tartary. Of these, however, little is known, although it is expected that the extension of archæological research to Bokhara will throw much light upon the former state of civilization in these distant regions. Be this as it may, the sacerdotal power was once more triumphant in Asia, but with a new faith; and while every branch of science had its patronage, medicine in particular met with every encouragement. The Arabs generally had not only a strong liking for medical studies, but there is reason to think that the prophet himself was a student of medicine and a medical author. The schools at Alexandria appear to have been also re-established, for mention is made of professors there so late as the close of the seventh century; and at the commencement of the ninth, the patriarch of Alexandria was so celebrated for his medical skill, that the Caliph Haroun-al-Raschid sent for him to visit one of his sick wives.

The Pandects.
A.D. 687.

Syriac translations of the Greek medical writers were made a few years previously to the capture of Alexandria, which were termed Pandects. Through these the Arabians acquired a knowledge of European science. In 687 they were translated into Arabic. In 767 Bagdad was founded by the Caliph Almanzor the Victorious, a great patron of science. He was attended in a severe illness by George Bactishua, an Indian physician, who had been educated at Nisabur, the capital of Khorassan, long the seat of an important medical school. Bactishua was most graciously received by the caliph, and at his departure was presented with the imperial fee of 10.000 gold pieces. At the caliph's request he translated numerous medical works into Arabic. The great translator, however, was Honain, a Christian well acquainted with Greek, Syriac, and Arabic, and possessor of a library rich in works on every branch of science. It is stated that the Caliph Almamon paid him in gold, for translating Aristotle, a sum equal in weight to each volume of his translation. He was known as Honain the Translator. His example was followed by his son Isaac, and his grandson Hobaish, both of whom enriched Arabic literature by translations of the best European writers.

Era of Haroun-al-Raschid.
A.D. 784.

The fifth caliph of the House of Abbas, Haroun-al-Raschid, was remarkable for his love of science. He welcomed scientific Christians to his court, adorned Bagdad with colleges and hospitals (which were added to under Almamon), until it rivalled Alexandria and Athens as a seat of scientific culture, and contained not fewer than 6000 learned Christian exiles within its walls. He it was who first set the example of attaching to every mosque that was built a college and an hospital,—an example which was most strictly followed by the Spanish Moors. The most distinguished medical professor at Bagdad at this period was Mesue, the son of a druggist, born at Nisabur. The pupil of Gabriel, the son of George Bactishua, he was especially commissioned by Haroun-al-Raschid to collect and translate into Arabic all the Greek works to be met with in Ancyra or other towns in that part of Asia.

Almamon, the second son of the great caliph, ascended the throne in 840, and devoted himself with the utmost enthusiasm to the advancement of science. He collected the works of the learned from every quarter, applying, on the one hand, to the Greek emperors at Constantinople for assistance in his pursuits, and rendering the Sanscrit literature available on the other. He erected observatories, and had astronomical instruments constructed for the purpose of facilitating astronomical observation. He derived much knowledge of astronomy from Hindustan.

Rhazes.
A.D. 882.

Rhazes was born in the year 852 at Rei, a city of Persia, and educated at Nisabur. At the age of thirty he removed to Bagdad, where he subsequently attained to a high reputation. He was a voluminous writer, but the greater number of his works were compilations from the Greeks. He wrote original works; amongst these is a treatise on small-pox and measles, which was translated into Greek at the desire of one of the Byzantine emperors.

Culmination of Arab medicine in Asia.
A.D. 1036.

The beginning of the eleventh century witnessed the highest development of Arab culture in Asia.

Avicenna.
A.D. 980.

Haly Abbas and Ebn Sina, or Avicenna, were nearly contemporaries, and both copious Arabian writers. The former has left a full account of the state of medicine amongst the Arabs, and a history of their medical writers. About the year 980 he wrote a voluminous work, intended to be a complete system of medicine, which he called *Almalecus*. But Avicenna was the Galen of the eastern Arabian empire. His great work was entitled the *Canon*, and became the text-book of Arabian commentators and teachers during the twelfth and thirteenth centuries. It had also an extended reputation in Europe even at an earlier period, which it maintained until the revival of letters. Avicenna died in 1036. Besides medicine, he cultivated philosophy, mathematics, and politics, and was at one time vizier to the sovereign of Hamadan. Only one other name appears in the history of the caliphs of Bagdad in connection with medicine,—that is Abdallatif, contemporary with Saladin. While that prince was at Jerusalem after the peace was concluded with the Christians, he gave lectures in the temple.

Decline of Arab medicine in Asia.
A.D. 1242.

At the time of Avicenna the caliphate of Bagdad had already gone through the same changes as the Roman empire at the time of Galen. The body-guards of the Caliph, the head of the faithful, possessed the same power as the prætorian guards of Rome. The distant regions of the empire were being attacked by the Turks, and various provinces formed into independent kingdoms under military commanders. Henceforth medicine made no progress amongst the Arabs. The physicians were little better than commentators and theorists. It was the period of political and religious decay. The Turks finally conquered Bagdad, and swept away all traces of science.

Rise of Arab Medicine in the West.

Rise of Arab medicine in the West. A.D. 748.

Medicine, in common with other sciences, found amongst the Mohammedans of the West the same support and encouragement as amongst those of the East. In the year 711, the Arabs penetrated into Spain from Africa, and laid the foundation of the Moslem empire in Western Europe. For nearly fifty years it was a distant dependency of the eastern seat of Arab power, and exposed to civil wars; but when the Ommiades or Beni Umeyah dynasty was overthrown by the Abassides in 748, a descendant of it, Abd-el-Rahman escaped from Bagdad and took refuge in Spain, where, after a series of conflicts, he established himself in the government, making Cordova his capital. His successor, the third of his name, who reigned in the tenth century, was the greatest monarch the Spanish Moors ever had. He followed in every respect the example of Almanzor and Almamon at Bagdad. He fostered every kind of science and art, founding colleges, schools, libraries, and constructing roads, canals, and aqueducts. The impulse then given was continued during the reign of his son and successor Al Hakem II., who, himself a scientific man, had an unbounded love for science and literature. He attracted the learned men of every country to his court, and founded the library of Merwan, of 250,000 works, at Cordova, the unfinished catalogue of which filled forty-four folio volumes. Within five hundred years from the conquest of Spain by the Arabs, science had been so developed that it could boast of seventy public libraries, three academies at Seville, Toledo, and Marcia, besides the world-famous university of Cordova, and hundreds of authors and teachers.

Culmination and Decline of Arab Medicine in the West.

Its culmination. A.D. 1150. Avenzoar.

Avenzoar was the Galen and Avicenna of Spain. He was rich, of noble birth, but a Jew both by religion and race. His father and grandfather were equally men of high reputation in the medical profession, as indeed was his son. A learned commentator, he was also an original observer, so that his works were hardly less valued in the scientific world than those of Ebn Sina. He flourished at the beginning of the twelfth century. Averrhoes was junior to Avenzoar, but also a contemporary, being his reputed pupil. He was educated in the university of Morocco, where he first studied law, but which he abandoned for medicine, mathematics, and philosophy. His father was the high-priest and chief judge of Cordova, and to these offices he succeeded on the death of his father. He was, however, subsequently deprived of them, and thrown into prison for his avowed scepticism. He illustrated the Aristotelian philosophy, from which circumstance he acquired the surname of "The Commentator;" and he wrote a system of medicine expressly intended to be a compilation. Averrhoes died about 1206.

Its decline. Albucasis. A.D. 1300.

Science was thus at its culminating point in antagonism with traditional theology. Concurrently the Moorish empire was declining, and at last was rent by bloody civil wars. The great battle of Las Navas, fought in 1213, struck at the root of the Moorish power. In 1226 Cordova, with its famous university, was surrendered to the Christians, and the Moorish King of Granada purchased peace by becoming the vassal of Ferdinand III. Spanish literature, arts, and science, declined with the declining power of the Moslem, so that Albucasis, the last of the Moorish practitioners of Spain, and who lived about the beginning of the fourteenth century, writes of surgery as being at the lowest ebb.

Its extinction. A.D. 1453.

Spain still retained, however, her universities and much of her learning after the expulsion of the Moors. In 1512 George Almenar published on syphilis; but the succeeding Christian governments fell under an exclusively sacerdotal and fanatical influence. The Jews and Moslems had been, and were, the chief supporters of science; but that scientific toleration which the latter had accorded to all creeds was not accorded to them. Jews and Moors were diligently extirpated by the Inquisition; their literature was pronounced devilish,—themselves accursed. This priestly blight of science fell upon Spain at the identical epoch when the rest of Europe was beginning to cultivate every branch of human learning, and is felt in that country to this day. So ended Saracenic medicine.

CHAPTER II.—MODERN OR EUROPEAN MEDICINE.

SECTION I.—FIRST PERIOD: FROM THE DARK AGES TO THE REFORMATION.

Sacerdotal Stage of Modern Medicine.

First period of modern or European medicine. A.D. 466 to 1453. Sacerdotal stage.

The imperial dominion of Rome virtually ended with the capture and sack of the city by Ricimer in 472, and actually with the abdication of Augustulus in 476. This finished the succession of phases of ancient European society. Commencing with the sacerdotal power of the old priesthood, it had ceased with the fall of the military hierarchy, and once again the whole series began anew with a new faith and new races of men. Amidst the troubles of the dying empire, the municipalities had held to laws and government, and the people had found the best guarantee for peace and order in the superior wisdom and influence of the clergy. It was, however, in 466 that the sacerdotal period of modern European civilization formally commenced, in which year the Bishop of Rome (henceforth to be so powerful) was elected to fill the episcopal chair by the united voice of the clergy and people. From this date, the sacerdotal caste was gradually but surely to rise above the military, and become predominant; not by means of a conquering prophet or a military caliph, but by a reconstruction of the framework of society on the first principles of human nature. The period between the close of the fifth and the middle of the seventh century was occupied in a slow but gradual civilization by religion of the barbarous populations of both the West and the East. As a consequence, we see a gleam of light bursting forth at last in the eighth and ninth centuries over the whole earth, from Ireland in the west to the farthest east of Bokhara and Hindustan. It was a period of a grand onward movement of the human mind from that state of degradation to which the old pagan idolatry (commencing first with symbolism) had reduced it. We have already seen what the monotheistic priesthood and warriors effected in Asia.

Charlemagne. A.D. 771.

Charlemagne in the eighth century rivalled his contemporaries, the caliphs of Bagdad, in his encouragement of the arts and sciences. In his reign the cathedrals and monasteries of Christendom, like the mosques of the Moslem, had libraries, schools, and colleges attached to them, in which medicine was taught in especial under the name of physics, or the philosophy of nature. Priests, abbots, and bishops were students of medicine and the physicians of kings. Nay, even abbesses and nuns studied and practised the art. While the Arabs were encouraging the sciences and arts in Asia, Africa, and Spain, Alfred of England was endeavouring to develope them in Britain. The epoch was in fact one of general revival of science and civilization; but its onward movement was interrupted by the continual attacks of the pagan barbarians of the North on the one side, and the Moslem on the other. The former at last got possession of the fairest provinces of Northern Europe, and with them ignorance and a retrograde social condition of that country came on. In the regions of Europe most distant from their attacks, as Italy, the south of France, and Spain, medical and general science continued to advance up to the close of the thirteenth century. Salerno, in the south of Italy (the old Magna Græcia), which

Alfred of England.

Constantine of Carthage. A.D. 1075.

was already in high repute as a medical school so early as the eighth century, maintained an eminent position from the tenth to the thirteenth. Constantine of Carthage, one of the professors during the latter half of the eleventh century, travelled, like a second Pythagoras, in search of knowledge through Egypt, Ethiopia, Arabia, Persia, and India,—countries in which the natural sciences and the arts were at their zenith under the caliphs, and would doubtless return, like his great predecessor, well stored with the philosophy and medical science of the East. Probably the development and vigour of this school was due to its proximity to the East. Portions of Naples also maintained close ecclesiastical relations with the Byzantine empire for several centuries, and the old Greek culture flourished there for a longer period than elsewhere in Europe.

Rise of a Medical Profession in Europe.

Medical profession in Europe. A.D. 1100 to 1453.

During this period the people inhabiting the shores of the Mediterranean went through the successive phases we have repeatedly traced already. Commerce introduced wealth,—wealth was followed by science and arts; then freedom of opinion was demanded, and the power and dogmas of the priesthood questioned: this in return appealed to the military power. Next arose the old conflict between traditional dogmas and new opinions, with a loosening of the ties of society, to end in the loss of political and religious freedom.

Era of the Troubadours, 12th century; and foundation of universities.

Thus in these regions the twelfth, thirteenth, and fourteenth centuries were remarkable for great commercial, religious, and intellectual activity, and an attempt at a reformation of religion, upon this followed the establishment of the Inquisition and the wars against the Albigenses. The sacerdotal power triumphed and became absolute; and the next phase came. It was now that the practice of medicine was separated from the priestly caste, and declared to be incompatible with the sacerdotal office. For several years decrees of councils and bulls of popes were launched against the combination of the two by the priesthood. Science and philosophy were thus secularized, for the study of medicine was then (as since) the study of all branches of human knowledge; hence another important social change arose. The cathedral schools were very generally erected into universities by the popes of the twelfth, thirteenth, and fourteenth centuries; science and literature thereby received the highest patronage, a home, and a special organization, and with these advantages they were rapidly developed. Encouraged by popes and prelates, the acquisition of literature from all available sources became an enthusiastic pursuit. The schools of the Moslem and Greek were visited, and their great medical and scientific authorities commented on and used as text-books. In short, it was an anticipation of the age of Leo X.

Albertus Magnus. A.D. 1256.

Of the mixed scientific and medical authors of this era, Albertus Magnus and Roger Bacon are the two most distinguished; the one a prelate in high favour with the papacy, the other a Franciscan priest alternately encouraged and persecuted. Both took a grand and comprehensive view of natural science in its practical relations, and included therein medicine and its accessory departments.

Mondini. A.D. 1316.

Practical anatomy was restored by Mondini, professor of medicine at Bologna, in 1316. He dissected the bodies of two women, and published a work on anatomy with plates. Surgery and medicine were advanced by Arnold de Villeneuve and Guy de Chauliac. The former travelled into Moslem Spain at the close of the thirteenth century, to be instructed in Arabian pathology, materia medica, and chemistry. It was here that he probably acquired a knowledge of alcohol, of which it has been alleged he was the discoverer. The name is manifestly of Moorish origin.

Guy de Chauliac. A.D. 1350.

Guy de Chauliac was a representative man, and deserves special notice. He flourished in the middle of the fourteenth century, and was one of the learned surgeons of this epoch. He had mastered Arabic and Greek literature, and his writings constituted a summary of all the then existing knowledge, and took rank with the established authorities of medical science and art. They were adopted as text-books for both professors and practitioners, and were translated and commented upon by the learned of all nations.

Extinction of Troubadour learning.

During this entire period the sacerdotal power was irresistible. At the beginning of the thirteenth century an attempt was made to assert and maintain religious liberty in both the south of France and in Italy, and the former at last became the seat of bloody religious wars, in which the dawning Reformation was finally quenched in blood. In Italy the Inquisition was put into full operation, and the heretics were unsparingly persecuted during the whole of the thirteenth and the beginning of the fourteenth centuries. Medicine and the natural sciences did not escape. Roger Bacon suffered the same fate as Galileo in the succeeding epoch, two centuries later; and the Inquisition tried Peter de Apono, a physician and naturalist, for heresy, after his death, and ordered his body to be disinterred and burned. In this age, therefore, there arose a bloody struggle between religious truth and corrupt traditions, and between natural and experimental science and the dogmatic theology based on the philosophical speculations of Aristotle. The latter was victorious. The sacerdotal power exercised a triumphant tyranny over the people, and so became more and more wealthy and corrupt. From this date a sensible decline may be observed in medical science and art for a century.

SECTION II.—SECOND PERIOD OF MODERN MEDICINE: FROM THE COMMENCEMENT OF THE GREAT REFORMATION TO THE FALL OF THE SACERDOTAL POWER.

Phase of Development under the Priesthood.

Second period of modern European medicine. A.D. 1450.

At the commencement of the fifteenth century commerce had acquired an extraordinary development in Italy and along the shores of the Mediterranean, and therewith the arts and sciences,—for they always follow in its train. Before its close, editions of the Greek and Latin classics, hitherto only to be met with in manuscript, were printed. Andreas Verrochio, the director of the Academy of Arts at Milan, and the master of Leonardo da Vinci, impressed upon artists the necessity to excellence in art of anatomical knowledge. Da Vinci (born in 1452) carried out these ideas into practice, and carefully dissected the human body at Vaverola. He made very many beautiful anatomical drawings, which still exist. Da Vinci was also an observant physiologist, a profound mathematician, a skilful architect and engineer, as well as a painter and sculptor.

The period was in truth one of immense progress in every direction. Society was more and more consolidated, commerce extended, political freedom developed. It was, like the period of the Greek republics, an age of large cities and small independent communities, the rulers of which encouraged science and art and learning by all the means in their power.

The Medici. A.D. 1389-1521.

The first manifest movement arose with the wealthy merchants and republican governments of the large commercial cities of Italy. As they declined from intestine wars and feuds, the military power usurped authority, and the republics fell under the power of successful military commanders; yet, nevertheless, these also continued the public patronage of science and art already begun. The history of the Medici family of Florence, in its relations to philosophy, science, literature, and the arts, from Cosmo the *Pater Patriæ*, born in 1389, to Leo X., who died in 1521, is in fact a history of what this class did for science in all parts of Italy. Giovanni de' Medici died, in 1428, a wealthy and successful merchant, leaving two sons, both of whom, as well as their descendants, occupy an important position in the story of Italian progress. Cosmo the Elder continued the extensive commercial enterprises of his house, and at the same time surpassed almost all the princes of Europe in his munificent support of literature and science. He founded a philosophical academy at Florence; collected, by means of his numerous commercial agents, the Greek, Latin, and Arabic MSS. which formed the basis of the Laurentian Library; and administered a liberal hospitality to learned men. He died in 1464. His grandson, Lorenzo the Magnificent, carried on the scientific and literary enterprises which Cosmo had begun. He also encouraged the cultivation of the Platonic philosophy; collected MSS. from every quarter, but especially from the East; and when the art of printing was discovered, instigated the publication of collated and correct editions of the classical writers. On the capture of Constantinople by the Turks, he welcomed and employed the learned Greek refugees as professors and teachers of the Greek language, literature, and philosophy.

Age of Leo X. A.D. 1513.

Leo X., a great sacerdotal ruler,—the Haroun-al-Raschid of his era,—was the son of Lorenzo the Magnificent, and trod in the steps of his ancestors in their patronage of literature. He founded a Greek college at Rome; established a Greek press under the management of John Lascaris, who had brought 200 MSS. from the East for his father; restored the university of Rome in all its departments; collected all available talent about him, whether of science or art; and took every possible means to add to the literature of the times. This was "the age of Leo X." It was the culminating point of European mediæval civilization and science, and the hour of final departure of the old Greek. Its great characteristics are two,—the restoration of Greek philosophy and literature to Europe, and the discovery of the art of printing. Henceforth science was to march forward independently of kings and priests; with a printing-press it passed over to the people, and there won a dominion of its own.

Linacre in Italy. A.D. 1484.

Fernel.

The immediate effect on medicine of the capture of Constantinople was to give a new impulse to the cultivation of Greek medical science and literature. The learned fugitives who became teachers of both the Greek medicine and philosophy in the Italian universities and academies, attracted to their lectures enthusiastic students from all parts of Europe. In 1484 Thomas Linacre, the founder of the College of Physicians of London, left Oxford for Florence that he might attend the lectures of Demetrius Chalcondylas, an Athenian refugee, and became at the same time an inmate of the palace of Lorenzo de' Medici, as companion to that prince's children. From Italy the taste for books, libraries, and sound learning was diffused over Europe. A great number of ancient works were edited, translated, and commented upon. The authenticity of MSS. and the purity of texts were closely scrutinized; and finally the great mass of Greek and Arabian medical literature was irrevocably made European. In little more than a century from that date, Anuce Foes had completed his great undertaking,—the first and best Latin translation of the Hippocratic writings. Concurrently with this important movement, original authors arose in great numbers, who contributed to its progress, or summarized the results. Of the latter class was John Fernel, born in 1497 at Clermont, and physician to Henry II. of France. He was both a Greek and Arabic scholar, a profound mathematician, and an original thinker. He boldly questioned the dogmas of Galen, then almost considered sacred, and gave a new impulse to systematic medicine. He was, in fact, the Ebn Sina and Galen of his epoch.

Phase of Conflict with Sacerdotal Power, and Decline of the Latter.

Phase of conflict of modern medicine.

Decline of sacerdotal empire. A.D. 1517.

It may facilitate the comprehension of the true position and character of existing modern medicine to look back upon the long and devious course we have travelled, extending, indeed, over 3000 years. Our first glimpses of medicine show it in intimate connection with sacerdotal predominance in India, Egypt, Judea, Phœnicia, Greece, as far back as we can see in its history. Fifteen centuries of the Christian era have elapsed, and we find it in intimate connection with sacerdotal predominance still. The head of sacerdotal power of Christendom bears the title of Pontifex Maximus, like his Egyptian prototype and his Roman predecessor; and that power has been predominant for more than 1000 years. Already, in the fourth century, the bishops and clergy were the ruling municipal authorities; and when the Bishop of Rome assumed and asserted supreme power over all other authority in Christendom, he was but the proclaimer and impersonation of a long existing reality. But that power is at its culmination, for we find all those phenomena in the development of medicine which mark an epoch. Religion is, in fact, no longer the binding tie of society; the head of the church hardly thinks it necessary to be even of good moral conduct; the augurs laugh in each other's faces; and the financial, æsthetic, and scientific development of the church is at the highest. For all that, the decay of the sacerdotal empire of Rome has already commenced. The new reformation begun in Italy at this epoch by Savonarola and others was quickly quenched in blood, as in the thirteenth century; but the field of conflict was wider than in that period, and in a few years it burst forth in Germany. There Tetzel was as impious with his indulgences as Alexander when he assumed to be Jupiter, or as the Roman emperors when they proclaimed themselves to be divine. Savonarola was executed on May 23, 1498; Luther affixed his ninty-five propositions to the gate of the castle church of Wittemberg on 31st October 1517. From that day commenced the disruption and decline of the sacerdotal empire in Europe. Since then the seat of sacerdotal power has been transferred to the north-east, and the Emperor of Russia wields the dominant sacerdotal sceptre of the world. He it is who, from small beginnings at this era, has risen to be the usurping head of the Greek church, with his chair fixed temporarily at Moscow, but his hopes on Constantinople. All experience shows that the course of the sacerdotal czars will be necessarily militant and aggressive,—that is, conquering. The head of the Mohammedan priesthood is all but defunct; his extinction is but a question of time and accident: he is a political necessity only,—a Turkish high-priest supported by Christians.

It was not long before medicine experienced in Italy, in common with the sciences generally, the consequences of the change we have described. The impulse given to them during the era of the free commercial republics ended finally in depression under a leaden despotism. Throughout France and Germany the era of those religious wars succeeded which thinned the population, devastated towns, interrupted commerce, and by again rendering the sacerdotal power secure, although with diminished empire, laid the foundation for the great revolution which commenced at the close of the eighteenth century. Great Britain and the Baltic states being remote from the thick of the fight at the great Reformation, happily escaped in great measure: the north of Germany sank down exhausted.

The true basis of modern civilization.

The discovery of printing placed the means of acquiring knowledge in the hands of the people. Protestantism demanded and obtained for them the right to the free use of those means. The great political principle of Christianity, that all men have equal rights before God and the law, became an article of faith both political and religious. It is upon this principle that the true European civilization is based; all others are but a continuation of the old and really oriental civilization. Hence the Reformation was the great *punctum saliens* of a new form of social life destined to be ever in conflict with the old; and to the countries of the Reformation medical science at last fled. While, then, the centre of sacerdotal empire has passed from Rome to Moscow, the centre of commercial and scientific empire has passed over to London and the universities of Great Britain. Remarkable is it to see this empire already confronting the great sacerdotal ruler of the world in both Europe and Asia, and supporting politically the two decaying priestly rulers of Rome and Constantinople, as a counterpoise to the younger and more vigorous. Remarkable is it, too, to see that her language is spreading through every region; that her scientific arts are changing the face of civilization by giving an incalculable increase of social and material power to man; and also, which is more to our purpose, remarkable is it to see that she is restoring medicine and the arts to those countries from whence, in connection with the sacerdotal form of government, they seem to have originally sprung. British medicine has taken root in both India and China. In India, schools, colleges, libraries, are established and multiplying, and the educated natives acquire a knowledge of English science and literature as the ancient world of Europe sought a knowledge of Greek, and the mediæval of Latin. The history of medicine may with justice, therefore, be especially associated for the future with its progress in Great Britain.

SECTION III.—THIRD PERIOD OF MODERN MEDICINE: FROM THE REFORMATION TO THE CLOSE OF THE NINETEENTH CENTURY.

Origin and Development of a Medical Profession and Medical Literature in Great Britain.

British medicine. A.D. 1518 to 1800.

16th century. Linacre. London College of Physicians.

Linacre proceeded from Florence to Rome, and studied medicine and natural philosophy, applying himself more especially to the works of Galen and Aristotle. Having graduated at Padua, he returned to Oxford, where he gave temporary lectures on physic, and taught the Greek language. Henry VII. employed him professionally; and he stood high with his successor Henry VIII., who patronized men of letters. Cardinal Wolsey was like-minded, and, as the result of this patronage, it was stated that the English court contained more men of learning than any academy. Thus dawned the Elizabethan age in England. At this time the bishops in their several dioceses had the power of granting licenses to practise medicine. It was therefore followed as a profession chiefly by illiterate monks or by unlicensed empirics. To remedy this evil, Linacre exercised his influence with Wolsey, and procured letters patent, dated 1518, founding a college of physicians in London, and was elected the first president. He entered into holy orders before he died. (See LINACRE.)

Kay.

John Kay, born in 1510, succeeded Linacre. He founded the only medical college existing at Cambridge. Like Linacre, he was an erudite physician, and studied Greek and medicine in Italy as well as at home.

17th century. Harvey.

Harvey lived at a time when the novelty of Greek literature had passed away, and men's minds were turned to original research. Like Linacre, he graduated at Padua, where he studied anatomy under Fabricius ab Acquapendente. Returning to England, he made the famous discovery of the circulation of the blood. (See HARVEY.) Sir Thomas Brown, the author of *Religio Medici*, was his contemporary, but his junior.

Sydenham.

Sydenham was another of the first great English physicians who were born and educated before the civil wars. He has raised the name of English medicine as high as any. Montpellier was then a celebrated school of medicine (for the Italian schools were already declining), and to this Sydenham repaired after graduating at Oxford. Like Harvey, he took a side in the civil war, but as a parliamentarian, and was more of a partisan; Harvey being the physician to Charles I., remained simply faithful to his friend and king. Sydenham was, however, younger than Harvey by 46 years, the date of his birth being 1624, when the discovery of the circulation had been already before the scientific world for four years. These two men initiated great changes in medical science.

Riolan.

Anatomy. Malpighi.

Pecquet.

Physiology. Mayow.

Chemistry.

Paracelsus.

Several distinguished men arose on the Continent at this epoch, and influenced the progress of medicine. John Riolan of Paris was the principal opponent of Harvey, and being the greatest anatomist of his age, his opinions had much weight with his contemporaries, and delayed the recognition of Harvey's discovery by the medical world. When at last it was accepted, the changes in medical researches and theories were rapid. Malpighi, working in 1661 with the microscope, demonstrated the motion of the blood-corpuscles in the capillaries. The discovery of the anatomy of the lacteal vessels (1647) by Pecquet, a student at Montpellier, had already overthrown the current theories as to the relations of the liver to the circulation; and in 1661 Malpighi showed the true anatomy of the pulmonary tissue and its relation to the circulation. Hence arose new theories of nutrition, respiration, and circulation. In 1668 Mayow approached very near to the modern theory of respiration. While anatomy and physiology were advancing with such long strides, all the other branches of medical science were progressing too. The cultivation of the occult sciences had led the physicians and philosophers of the latter end of the fourteenth and the beginning of the fifteenth century to Arab literature; and knowledge acquired by the Moorish chemists, especially of Spain, was applied to medicine. Thus the foundation of modern chemistry was laid. Very soon the principles of the science were applied to anatomy, physiology, and pathology. In 1527 Paracelsus was professor at Basle, teaching a strange mixture of magic, astrology, geomancy, and medicine, and introducing powerful chemical remedies into practical medicine, especially mercury and antimony. He commenced his first course by publicly consigning to the flames the works of Galen and Ebn Sina. A century later Van Helmont partly founded the iatro-chemical school of which Sylvius, or Francis de la Bois, professor of medicine at Leyden in 1648, was the most distinguished ornament on the Continent, as was Willis in England.

Medical psychology. Willis. A.D. 1659.

Thomas Willis was one of the physicians of the time of the great civil war. He took the side of the king. At the Restoration he received the appointment of Sedleian professor of natural philosophy in the university of Oxford. In the preceding year (1659) he had already published chemical theories of fever and of the urine, in which he adopted the doctrines of Sylvius. Willis was, however, more remarkable for his researches into the anatomy, physiology, and pathology of the brain. He it was who first distinctly advanced and applied the modern doctrine, that the brain is a congeries of organs, and who especially assigned the cerebellum to the involuntary movements. Van Helmont in the preceding century had broken the ground of physiological metaphysics, and had theorized on the *Archæus*. Willis, following Van Helmont in this department as well as in that of iatro-chemistry, entered into those profound metaphysical discussions which then occupied the greatest thinkers of the day, such as De la Bois, Descartes, Newton, Leibnitz, Locke, Hobbes, Grew, Sydenham (in his *Theologia Rationalis*), Wedel (of Jena, then a renowned university); and, later on in the century, Hoffmann and Stahl. Willis was a man of great practical piety. He appropriated all his Sunday fees to charitable purposes; he procured a service to be performed early every morning in a church in St Martin's Lane, that he might be able to attend before he visited his patients; and he dedicated his treatise *De Animâ Brutorum* to the Archbishop of Canterbury. All this did not prevent the calling in question of his orthodoxy by the theologians; for the old sacerdotal spirit of unquestioned predominance and Aristotelian preference still remained in the reformed clergy.

Midwifery. Mauriceau. A.D. 1668.

Midwifery first took its origin in this century as a distinct department of medicine. The *sage-femme* of Marie de' Medicis published in 1609 or 1626 a collection of obstetrical observations; and in 1668 the appearance of a formal treatise by Francis Mauriceau, chief accoucheur to the Hôtel Dieu in Paris, laid a stable foundation for the science and art.

Surgery. Wiseman.

Surgery had not such a crowd of promoters as the other branches of medicine. Foremost amongst them was Richard Wiseman, surgeon to Charles I. and his son during the civil wars. He was taken prisoner at the battle of Worcester. At the Restoration he was appointed serjeant-surgeon to Charles II.

Botany. Gesner. Grew and Ray.

Botany had already been largely advanced in connection with materia medica in the sixteenth century. Its revival arose partly from the efforts of commentators, as Anguillara and Facho, to illustrate the older writers, partly in the occult doctrine of signatures adopted by mystics like Paracelsus, Baptista Porta, and Crollius. Conrad Gesner of Basle principally laid the foundations of modern botany in the middle of the sixteenth century. He was followed by Andrew Cæsalpin and others. In England Grew, in the year 1682, advanced vegetable anatomy and physiology far beyond his contemporaries; while John Ray laid the foundations of zoology as well as of English botany. Woodward, one of the founders of English geology, belongs more to the next century.

Animal mechanics. Borelli. Pitcairn.

Mathematics was much cultivated at this time, but more particularly in reference to dynamical philosophy. Two natural philosophers, Sir Isaac Newton and Leibnitz, were at the head of the mathematicians; but several physicians engaged in the study, and applied the science to medicine. These were the iatro-mathematicians. The discovery of the circulation and of animal mechanics in connection with anatomical research, naturally led to this method of investigation. Borelli of Pisa was the founder of the sect. The first volume of his great work *De Motu Animalium* was published at Rome in 1680, the year after his decease. Bellini, his pupil, followed up his views; and later on, Baglivi, the Roman Hippocrates, applied them to pathology. In Great Britain Archibald Pitcairn of Edinburgh, the pupil of Bellini, applied mathematics to medicine. It was, however, in the beginning of the following century that these iatro-mathematical theories received their full development.

This very general and rapid survey of the state of medicine in the seventeenth century will at least suffice to show that it advanced more in every department during that stirring period than in any preceding century, not excepting that in which the school of Alexandria was established. The age was one of progress throughout. The impulse given to learning during the close of the sixteenth century was felt in every department of human knowledge; nor did the civil wars in Great Britain and Ireland at all diminish its effects; perhaps they rather kept it up by developing men's energies.

Foundation of medical societies. Origin of the Royal Society. A.D. 1645.

The most striking event of this epoch in the history of medicine is the foundation of the Royal Society of London, the first of the kind constituted out of Italy. It is of sufficient importance to merit special notice. We have seen that in the eighth century the learned societies were sacerdotal in their origin, being connected either with mosques, monasteries, or collegiate churches; that in the thirteenth and fourteenth centuries they were less sacerdotal, and appeared as universities, yet under the protection and control of the church. In the sixteenth and seventeenth centuries medicine (still as physics) had so widely extended its limits, that it required special institutions for their development, for in truth they comprise within them every branch of natural philosophy. The universities were leavened with the old Aristotelian philosophy; medicine wanted the new. The theologians were still predominant in them, and fettered inquiry; medicine wanted freedom. Politics were discussed with sword and gun; medicine wanted to seek after truth in peace. Hence it happened, that in the very hottest of the great civil war some of the most distinguished of the English school of medicine banded themselves with other investigators of nature, and, with their co-operation, finally established the Royal Society of London, the modern head and home of natural science.

Attacked by the sacerdotal power.

It is worthy of notice that the supporters of the sacerdotal power instinctively perceived the new society to be an enemy; and in 1667, seven years after its formal foundation, Dr Sprat, afterwards Bishop of Rochester, had to defend it from their attacks. It was objected that the society neglected the wiser and more discerning ancient philosophers, and depended too much upon their own unassisted powers; that, by admitting men of all religions and all countries, they endangered the stability of the established church; and, more than all, that a philosophy founded on experiment was likely to lead to an overthrow of the Christian religion, and even to a formal denial of the existence of God. It was on such grounds that the old Greek philosophers were persecuted to death. The Roman priesthood of Christendom had met the scientific men and discoveries of the two previous centuries in the same spirit and with the same argument. Unhappily for themselves and for religion, they also possessed the power of compelling at least an apparent submission to them. Galileo Galilei demonstrated the falsehood of the Ptolemaic system; but the priesthood had affirmed its truth, and as their authority rested on the assumption that they were infallible, to question their dogmas was to shake the very foundation of their power. Galileo was therefore compelled to recant his opinion, that the earth moved round the sun; but his whispered reservation of "It moves for all that," was as prophetic of the advancement of philosophical truth as of the certain recognition of his own doctrines.

Medicine in the eighteenth century. Clinical medicine.

In Protestant countries natural science was now free. The beginning of the eighteenth century was especially characterized by the establishment of CLINICAL MEDICINE, or bedside teaching on a systematic plan. The obvious necessity to the student of a practical acquaintance with disease must have been felt at all periods of the history of medical art. The simplest method of securing this to him would be for his master to take him to the bedside of the sick. In private practice the facilities for this method are limited by the inconvenience which is necessarily inflicted if any number of students enter private houses. Hospitals, therefore, or at least public institutions of some kind for the reception of the sick, have been usually used for this purpose. In modern times the first recorded attempt at systematic hospital instruction was made at Padua in 1578, About the commencement of the seventeenth century, Otto de Heurn introduced it at the university of Leyden.

Boerhaave. A.D. 1701.

The celebrated Francis le Bois succeeded him in 1658, and attracted numerous students for a period of fourteen years. The fame of Leyden as a medical school seems to have begun at this time. The method does not appear to have been continued after his death, or went on at least with much less *éclat;* but in 1701 Boerhaave, a representative man, was elected to the chair of the institutes of medicine, or physiology. He was destined to impress his character upon European medicine for half a century.

Hermann Boerhaave, the son of a country Protestant clergyman, resident two miles from Leyden, was originally intended for the church. At the age of eleven he could read Greek and Latin with tolerable accuracy. To these languages he added the study of Hebrew and Chaldee, with ancient and modern ecclesiastical history and mathematics. When aged twenty-one (in 1689), he took his degree of Doctor of Philosophy, and selected as the subject of his inaugural thesis, "the distinction between the soul and the body." This indicated the bent of his mind. He was taught mathematics that he might be able to pursue his studies in medicine; and finally, at the age of twenty-five, took the degree of Doctor of Medicine. Eight years afterwards (1701) he was appointed lecturer on the theory of medicine at Leyden; and in 1705 he became physician to St Augustine's Hospital, and lecturer on the practice of medicine. From this date he commenced systematic clinical medicine, and gave clinical lectures twice a-week.

Boerhaave was professor of both chemistry and botany at the time he held the chairs of theoretical and practical medicine. He was therefore an encyclopædist. His mathematical and classical knowledge made him a man of extensive erudition, so that he was admirably calculated for the duty of reducing to order and systematizing the vast mass of scientific materials which had been accumulating during the preceding century. He placed physiological science in immediate relation with pathological research; he advanced practical medicine in all its departments; he was the first to make chemistry intelligible and delightful; and he largely developed botanical science. His system of medicine was eclectic, and, in some way or other, comprised the doctrines of the ancients, and the views of the iatro-mathematical and chemical theorists, together with his own speculations as a blending medium. He was the Galen, the Ebn Sina, the Fernel of his age. Already, therefore, a social epoch is ending, and another is about to commence. Before the end of the century the old institutions of European society were being swept away; the sacerdotal power was being annihilated, and the "goddess of reason" installed in the capital of France, in which, within a few years afterwards, the representative of that power was a captive to the military. Standing a while at these epochs to look back, we see that human affairs ebb and flow in grand tides as regularly as the tides of the ocean; for a while they seem to be restrained within safe limits, but one wave at last surely towers high above the rest, and falls with thundering and irresistible force upon the shore. In such a catastrophe, although beginning so favourably, the eighteenth century closed. The retrospect is a warning to the present generation.

Histories of medicine.

Mead.

In England, at the beginning of the eighteenth century, there were men who belonged to an earlier period than Boerhaave, but they were engaged in the same work. Mead, like Boerhaave, was the son of a Protestant minister. He was educated at Utrecht, studied medicine at Leyden, but graduated in 1696 at Padua, then a famous school. In 1703 he became physician to St Thomas's Hospital, and lecturer on anatomy at Surgeon's Hall. He was physician to George II. when Prince of Wales, as well as after he ascended the throne. He was the friend and successor of Radcliffe; was a learned man; wrote elegant Latin; read Greek and Arabic. He translated Rhazes's work on smallpox and measles from the only remaining Arabic manuscript, supplied to him by Boerhaave. Like Boerhaave, he had a vein of piety in his character, and to this probably was due his work entitled *Medicina Sacra*. Freind, the friend and contemporary of Mead, wrote a history of medicine. This was also done by Le Clerc about the same time.

Freind.

Le Clerc.

Sloane.

To this era belong also Sir Hans Sloane, Arbuthnot, Garth: all learned men, collectors of manuscripts, books, coins, and the like; chemists, botanists, poets, and the associates of the literary men of the time, as Dryden, Pope, Swift, &c.

Clinical medicine at Edinburgh. A.D. 1741.

British medicine is closely connected with the university of Edinburgh from the close of the first half of this century. A chair of theoretical medicine and botany had already existed for several years, when in 1713 a chair of chemistry was founded. The success and the example of Boerhaave at Leyden were not lost upon the university, so that shortly after his death a chair of clinical medicine was established on the same model. There was no medical school at either of the English universities, and the schools of the metropolis had no collegiate character, and were imperfectly organized. Rutherfurd and Monro were the first clinical professors at Edinburgh; the one lectured on surgery, the other on medicine. Whytt, the Monros, and Gregory were eminent teachers and writers at this time, or a few years subsequently, all being more or less under the influence of Boerhaave. But the chief man of the Edinburgh era was Cullen. He it was who formed the principal link between the doctrines of Boerhaave and those which arose during and at the close of the great revolutionary wars. Associated in early life with William Hunter (with whom he always maintained a warm friendship), Cullen, after various struggles, commenced in 1746 a course of lectures on chemistry in the university of Glasgow. In ten years after he occupied a similar chair at Edinburgh. In 1763 he succeeded to the chair of materia medica; in 1766 to the chair of institutes of medicine, or physiology, and resigned that of chemistry in favour of Dr Black. On the death of Rutherfurd he was associated with Gregory as alternate occupant of the chair of practical medicine. That distinguished physician did not live long, and Cullen became the sole professor. Cullen, like Boerhaave, systematized medicine, which his varied knowledge and great original powers enabled him to do well. In this work Van Swieten in Germany was his rival. But during his career the spirit of original research and investigation was awakened, and although he began with a compiled exposition of the doctrines of Boerhaave, he ended with a set of doctrines of his own. Albert von Haller, his contemporary, was at the same time laying the foundation of a new system of physiology, and pursued the same course. Up to 1747 Haller had used the *Institutions* of Boerhaave as the groundwork of his lectures on physiology; but in that year he published his *Primæ Lineæ Physologiæ*, and thenceforth, to the end of the century, he was one of the great lights of medicine. In London, at this period, John and William Hunter laid the foundation of the English school of physiology.

Monro.

Whytt.

Cullen. A.D. 1756.

Physiology. Haller.

John and William Hunter.

Sacerdotal influence in 18th century.

At the same time that medicine began a fresh starting-point science and literature also took on a fresh development. Voltaire, although a few years senior to Haller, ran a course in philosophy and literature somewhat parallel. Religion at this time, as in the fifteenth century, had greatly ceased to be a reality, and had degenerated into ceremonial observances. The Jansenists, to which sect Voltaire's eldest brother belonged, had attempted a reformation, but were wholly scattered by persecution at the time that Boerhaave was at the height of his reputation; and the Roman priesthood had nothing better to offer to the people than a rigid adherence to ecclesiastical discipline and forms; that is, a submission to the power of the priests. In 1730 the celebrated actress Adrienne Lecouvreur was refused the rites of sepulture because of her profession. Voltaire wrote verses on the subject full of indignant invective, and from that time his whole life was a contest with the sacerdotal power. The reaction against the formality and laxity of the priesthood took place later in Great Britain than in Roman Catholic France, and did not begin, in fact, until the time of Wesley and others, when Jansenism was already extinct on the Continent, and the new reformation suppressed.

Natural science at the close of 18th century.

While religion decayed more and more, and the court, nobility, and higher clergy became more and more luxurious, science, as in former epochs, was continually progressing. An era like that of the close of the fifteenth century was, in fact, in full vigour; and a large number of scientific men were developing every branch of science. Medicine being so intimately related to every branch, largely participated in the movement. It would be a vain attempt to indicate in our limited space the progress made in each. It must therefore suffice to point out the grand advance made in what may be termed the science of matter, organic and inorganic, or chemistry. In Great Britain, Black, the friend of Cullen and Watt, led the way by his discovery of carbonic acid gas and the laws of heat; Cavendish discovered hydrogen gas; Priestly oxygen and other gases. These preceded Davy. On the Continent Bergmann and Scheele were working in the same direction, together with Guyton de Morveau, Lavoisier, Berthollet, Fourcroy, Klaproth, and others. A new nomenclature was given to the science, and it was re-cast from the foundation, and placed on a stable basis.

SECTION IV.—FOURTH PERIOD OF MODERN MEDICINE.

The first half of the Nineteenth Century.

Present era of European medicine.

At the commencement of the present century an improved chemistry, springing from the bosom of medicine, almost established modern civilization anew. On the one hand, numerous vital processes became intelligible, or at least it was at last possible to discover their nature by scientific research. Physiological science thus received an impulse, and therewith practical medicine, which even now is far from its maximum. On the other hand, the means of controlling nature, and of discovering her secrets, were placed within the hands of man. The laws of heat, as developed in steam, in metallurgy, and in manufactures; of electricity and galvanism; and of chemical affinity; have been applied to the practical uses of society, with results already so remarkable, that one mind would not suffice for their full expression. From the same causes, every kind of philosophical aid to research has been so improved that no branch of physical science is without good and appropriate instruments. Astronomy and meteorology have, however, most profited by them. The results of the last half century, as it regards medicine, will be best shown by a note, however brief, of the present state of medical science, and of the medical profession in the United Kingdom.

Present state of Medical Science in the United Kingdom.

Medical schools of the United Kingdom.

The extent of the teaching, and the number of subjects taught, constitute a measure of a science. The entire number of medical schools in the United Kingdom, not including Oxford and Cambridge, is 39. Of these, 12 are attached to the great hospitals of London, and 11 to those of large towns in England. There are 6 in Scotland, and 10 in Ireland. The entire number of recognised teachers in the various departments of Medicine cultivated in these schools is 493, being nearly 13 teachers to each school; besides tutors, private lecturers, and assistant lecturers. In the London schools there are 182; in those of the English provincial schools, 164; in Scotland, 68; in Ireland, 79. In Oxford and Cambridge there are 11 medical chairs, occupied by 9 professors. The entire number of students of medicine at these schools is about 3000, or about 1400 in England, 1000 in Scotland, and 600 in Ireland. With few exceptions, these institutions are wholly self-supporting, having no endowments from either private individuals or the state; in many instances the pecuniary remuneration is of trifling amount, and in some is even insufficient to meet the current expenses of the course of lectures.

Modern divisions of medical science.
Anatomy.

The subjects taught are from thirty to forty in number, and are divided as follows:—Anatomy, or the structure of the human body, has several subdivisions. First in order is general or descriptive anatomy, as the parent of all. Anatomical Demonstrations teach structure from actual dissection of the body. Histology demonstrates the minute anatomy or composition of structures as discernible by the microscope only. Comparative Anatomy (including palæontology) teaches the anatomy of the lower animals, with special reference to human anatomy and human physiology. Practical Anatomy is that branch which applies a knowledge of structure to the right performance of the operations of surgery. Pathological Anatomy points out the aberrations from the normal or healthy structure of the tissues or organs of the body.

Physiology.
Art of medicine.
Curative.

Anatomy is essential to a knowledge of healthy or of diseased function, or, in other words, to physiology and pathology. To both, but in particular to Physiology, are also subservient the departments of Organic Chemistry, or the chemical constitution and composition of living tissues and products in health and disease; Natural Philosophy in all its branches, except *medical meteorology*, which has not yet been taught separately; and Natural History, including Zoology and Botany. Pathology takes in a wide range, inasmuch as it includes the nature, causes, and symptoms of disease, or etiology, symptomatology, and doctrinal questions. The Art of Medicine is taught in the schools in numerous departments or subdivisions. First, as we have general or descriptive anatomy, so we have courses of general Practical Medicine, in which, in addition to general principles of treatment, the relief or cure of special visceral diseases, not included in special courses, is considered. This is Practical Medicine. Similar courses of instruction are given in Surgery and Obstetrics. All these, again, have their subdivisions. Thus, as subdivisions of practical medicine, Psychological Medicine teaches the nature and treatment of insanity, and *Epidemiology* treats of epidemical diseases. Surgery subdivides into Military *Surgery*, Operative *Surgery*, or practical training in the performance of surgical operations; and the surgery of the principal organs of sense, or Ophthalmic and Aural *Surgery*; to which may be added the treatment of diseases or defects of the teeth, or Dental *Surgery*. Obstetrics has the sub-departments of Operative Midwifery and Diseases of Children. Further, all the great departments of the art are systematically taught at the bedside in the principal hospitals. These are designated Clinical Courses. There are, therefore, courses of clinical medicine, surgery, and midwifery. Under this head Hospital Attendance, or "hospital practice," must be included.

Medicinal agents are largely used in every department of practice. These are included under the term Materia Medica, and courses of instruction are given as to their nature, composition, and uses. Subservient to materia medica are General Chemistry (comprising heat, galvanism, and electricity) and Medical Zoology and Botany. Therapeutics includes instruction as to the application and administration of every kind of remedy.

Preventive medicine.

The prevention of disease has not hitherto had that special attention devoted to it in the United Kingdom which it deserves, and as yet there are only three chairs of Public Hygiene. The subject has been usually included under etiology, practical medicine, and medical jurisprudence. In like manner, Dietetics (of which there are two chairs) has been usually included either in practical medicine or materia medica and therapeutics.

Political medicine

State medicine, or Medical Jurisprudence, is taught in all the schools, and discusses all questions of medical science and art bearing upon the administration of the law. Practical hygiene as to nuisances, disputed questions of mental capacity or moral responsibility on the ground of imbecility or insanity, and the causes and modes of violent death, are included under medical jurisprudence. Toxicology is one of its most important subdivisions, but has also relations to materia medica, pathology, and practical medicine.

The cultivation of all these departments of medicine, whether they be considered as branches of the science or of the art, is not possible without a knowledge of the means and modes of research available thereto. The principles

Instruments of research.

Medical logic.

of optics, acoustics, and hydraulics have been applied to the construction of several aids to the senses, of which the *microscope* and *stethoscope* are the chief. Skill in the use of these is part of the necessary qualifications of the efficient practitioner, and must be taught to the student. So also with the art of *chemical analysis*, whether inorganic, physiological, or pathological. The use of these and of other aids to investigation are taught in separate courses, or by separate teachers, in all the principal schools. In this department of medical art an immense advance has been made of late years. Perhaps from no quarter will so much advantage to medical science be derived, nor is it possible to divine to what extent our knowledge of human nature may be increased by the conjoint aid of those two potent instruments of research—chemical and microscopical analysis. After the training of the senses comes the training of the intellect. To this end a knowledge of LOGIC and of mental or moral philosophy is required. Only two of the medical schools of the United Kingdom (we except the universities) have chairs of logic. In this direction much has yet to be done in the culture of the professional mind. The defect being, however, felt, it will doubtless be remedied as opportunity serves.

Medical morals.

The medical profession has of late years endeavoured to define its duties and its rights. MEDICAL DEONTOLOGY or ETHICS has consequently received considerable development; and the fact that already there is one school in the United Kingdom having a chair of medical ethics, is an earnest that questions of professional *morals* are likely to have more and more attention directed to them.

Medical History.

The HISTORY OF MEDICINE, and its political and social relations, have also been treated in a separate course of instruction in one school. To the statesman and the intelligent layman it is a subject of great interest and importance. It cannot, however, be expected that these will occupy their minds with it when it is neglected by so large a number of the profession. The career of great conquerors, and the deeds of destroyers of mankind wholesale, are far more exciting themes than the silent unobtrusive doings of those who have preserved more lives than even the most ruthless conquerors have destroyed. The time will come, if modern civilization endures, when the moral grandeur of medicine will be acknowledged; then its progress will be felt to be one of the most interesting chapters of the history of mankind. That time, however, is not yet.

State of Medical Science Abroad.

Science breaks down the selfish barriers of states and nations, and gathers its cultivators into one great republic. This is particularly true of those who speak a common language and possess a common literature. Hence it is that the great republic of English medicine includes the medical schools of the United States of America and of the British colonies. Between these and the schools of the United Kingdom there exists the most intimate union, with a free interchange of knowledge. In the United States the number of schools and of teachers of medicine equals, if it does not exceed, that of the United Kingdom. It has been estimated that they are attended by 5000 students, and that 1000 of these graduate every year.

On the continent of Europe, the activity of medical life varies greatly according to the people or nature of the government. In France, Germany, Belgium, Holland, and Switzerland, medicine is cultivated as vigorously and as successfully as in the British or American schools. At Rome, Hippocrates is still commented on, as in the time of Leo X. In Italy generally (except Piedmont) and the non-German provinces of Austria, medical science is depressed; in Russia medical education, for the uses of the people at least, is by no means adequately developed, the few schools being wholly insufficient for so great an empire. Special departments of medicine have had a more diligent cultivation on the Continent than in the United Kingdom or the United States. This remark more particularly applies to medical police and public hygiene, which having had in the latter no encouragement from the state until of late years, has obtained no special attention. Late inquiries into the preventible causes of disease amongst the people of Great Britain, and the consequent establishment of boards of health, have laid the foundation for a new and most important department of practical medicine—the prevention of disease.

State of Medical Practice in the United Kingdom.

In all civilized countries the practitioners of the art are divisible into classes, the counterparts of which may be found in the United Kingdom, so that an analysis of British practitioners will apply, *mutatis mutandis*, to those of Europe and the United States.

Medical profession of the United Kingdom.

The practice of medicine is carried on in the United Kingdom by persons having various designations and qualifications. They may be divided into three classes. First are those who are "duly qualified" in virtue of having followed a prescribed course of study, and undergone successfully the examinations conducted by the collegiate or academical boards of examiners: this is the medical profession proper. Secondly, those who practise medicine as a business, yet have either not studied regularly or not at all, or having studied imperfectly, have no diploma or letters testimonial of having duly undergone an examination: these are empirics or "quack doctors." Thirdly, those who practise medicine as amateurs, or while engaged, ostensibly at least, in other pursuits: these are empirics also, but not professionally "quack doctors."

Qualified practitioners.

The qualified practitioners of medicine in the United Kingdom are known under various titles according as they follow one or another department of the art. The great proportion (about 20,000, or four-fifths) are *general practitioners* who, in accordance with the demands of thinly populated districts, or of the great majority of the population as represented by the middle and lower classes, minister to the people in every department of the art, and at the same time supply the necessary drugs and appliances. The metropolitan cities and the large towns have, in addition to these, a class of practitioners in special departments. There is the consulting or "pure physician," who excludes operative surgery, midwifery, and pharmacy from his practice. There is the "pure" consulting or operative surgeon, who practices neither midwifery nor pharmacy, but does not refuse his opinion in cases purely medical,—practising, in fact, as a surgical physician. The obstetric physician, while excluding pharmacy, and devoting himself more particularly to midwifery and the diseases of women and children, does not usually exclude the other departments of medicine. One or two minor departments of medicine and surgery are followed exclusively by a few individuals. The most numerous of these are the dentists, numbering about 1200 in the United Kingdom, who, however, are not for the most part "duly qualified" practitioners of medicine, but "mechanical" dentists. Of professed oculists and aurists exclusively there are very few, these usually combining general surgery with the practice of the special branch. In a similar manner, amongst physicians there are those who, having made a special study of special diseases, are specially consulted as to those diseases. Under this head are physicians skilled in the treatment of insanity and consumption, or diseases of the skin, the liver, the kidneys, the uterus, rectum, &c. The valuable discovery of anæsthetic medicines has called into existence another department, and this important class of remedies is already made a specialty in practice in the metropolis at least of the empire. In surgery a few "cuppers" still practise that branch of minor surgery exclusively. Chiropodists, or "corn-cutters," belong to the second class.

Sectarian practitioners.

Of late years a class of practitioners has arisen which, in so far as it is constituted of persons "duly qualified," may be designated *sectarian;* nevertheless, it is made up for the most part of charlatans. It comprises those who, whether duly qualified or not, practise medicine upon the basis of some exclusive dogma or principle, or with reference to some exclusive remedial agent. Legitimate medicine is catholic and eclectic; it has neither exclusive dogmas nor creeds; it requires its members to seek knowledge from every available source, and apply it in every available mode as may be demanded by the circumstances of the practitioner or the patient; the object of the exercise of the art being the relief or cure of the patient as promptly, safely, and pleasantly as possible, without any formal restriction as to the means or mode. This sectarian class therefore separates itself from the catholic profession by following professedly an exclusive method. Of the followers of Hahnemann (designating themselves *homœopathists*) there are reported to be about 300 in the United Kingdom. (See HOMŒOPATHY.) Of the followers of Priestnitz (the *hydropathists*) and of Mesmer (the *Mesmerists*) the numbers are much less. Indeed, the latter are not unfrequently homœopathists also.

Charlatan practitioners.

The "quack doctors" are a motley body, comprising every kind of specialty—worm-doctors, water-casters, bone-setters, astrologers, herbalists, "wise men," and "witch-finders" (who prove to be occasionally, as of old, professed poisoners and procurers of abortion), curers of syphilis and diseases of sexual organs (with hardly an exception a group of scoundrels), the "falling sickness," &c. In this class may be found also venders of secret remedies in connection with some absurd hypothesis, as *Coffin's* herbs, or *Morison's* pills; or itinerant practitioners of homœopathy, mesmerism, &c. The ranks of the quacks are also swelled by outcasts from the legitimate profession: men who are excommunicated either because of their vices or of their follies, and who have been morally punished by a *de facto* deprivation of professional intercourse with their brethren. In the third class of amateurs and others are comprised country clergymen, ladies having a taste for medicine, persons in private station with a smattering of knowledge, but especially the retailers and compounders of drugs, and professed nurses. Those who, when young, have abandoned or neglected the study of medicine as a profession, and have been led to follow other pursuits, are particularly apt to take up the irregular practice of it in after life.

Present Organization of the Medical Profession.

Its external organization.

The organization of the profession of medicine takes two directions,—an external and an internal. The external organization has reference mainly to the wants of the public or the state.

Public medical officers.

The army and navy have their respective medical officers; the public medical charities have their staff, comprising physicians, surgeons, obstetric physicians, apothecaries, oculists, aurists, cuppers; the medical relief of the sick poor engages the services of above 2000 practitioners. The public health is being gradually placed, in various towns and districts, under the cognisance of a body of special practitioners,—the medical officers of health; and the health of emigrants to the various colonies of the empire is committed to the care of surgeon-superintendents. These last are all practitioners in hygiene, as, indeed, are virtually the medical officers of the army and navy.

Its internal organization.

The internal organization of the profession has been determined by the operation of the great fundamental laws in virtue of which all human societies are constituted. So soon as the profession attained to a separate existence in the sixteenth century, the members thereof associated themselves together, and colleges of physicians were established. The humble assistants to the physicians of that era—the barber-surgeons and apothecaries—were also organized in like manner, but in guilds, which have developed themselves into colleges of surgeons or societies of apothecaries. Very lately the druggists or chemists (successors to the apothecaries of the last century) have organized themselves into "The Pharmaceutical Society;" and in like manner the surgeon-dentists propose to be incorporated into a college of surgeon-dentists. Nor has it been otherwise with the teachers of the different departments of medicine. With the development of the profession medical schools arose in the large towns, where only medicine can be taught in all its details—first in the metropolitan cities, then in the large manufacturing and commercial towns of the United Kingdom. Some of these are formally incorporated by royal charter; others, when firmly established, will undergo a similar change.

Medical corporations.

There are in all twenty medical corporate or licensing bodies in the United Kingdom. The colleges were originally founded in the metropolitan cities because the most active members of the profession were collected there in the greatest numbers. The same principle of combined action which led to their foundation has united the profession in other large towns, and in entire districts, in "medical societies" and "associations." These are virtually much of the nature of colleges; but the latter, starting from a legal basis and chartered rights, have gradually developed themselves into public authorities having control over the education of persons about to enter the ranks of the profession. That such control was, in the early history of modern medicine, most necessary and very useful, cannot be doubted; but the beneficial action of these colleges has not been had without some counterbalancing disadvantages. The corporate spirit is essentially contracted and narrow in its views; and the subdivisions in professional pursuits are apt to generate antagonism. The principal evil to which these colleges have given rise is, that the unity of all departments and branches of medicine, with reference to both its practical and philosophical relations, has been lost sight of. From this source has arisen much of the difficulty experienced for the last half century in the better organization of the medical profession.

Failure of attempts at legislation.

The repeated attempts made of late years to separate them legally by a sharp line of demarcation, and to arrange the practitioners of the various departments of the art in distinct legal classes, is but another form of the principle of caste, and which seems to have been strictly applied in ancient Egypt, where special practitioners abounded, and where they were restrained to their own department. Such legislation must always fail, for it is opposed by the ever vital principle of unity of the medicine. If rigorously carried out, decadence of the science and art is the inevitable result; if not rigorously carried out, the principle asserts its power as a disturbing agent. Consequently, whenever any special class of practitioners has arisen in this country, one or other result has followed. Having organized itself on the restrictive principle, its first efforts have been directed to a sharp limitation of its educational and municipal relations; but it has finally broken that limitation down, and returned to unity of teaching and of practice; otherwise it has gradually become more and more feeble.

Rise and fall of corporations.

The colleges of surgeons in the United Kingdom, first coming into existence as corporations of barbers and barber-surgeons, have constantly struggled upwards from that humble form of special practice, until at last their examinations and curricula of education are made to include, nominally at least, and their members practise, every branch of medical science and every department of medical art. The apothecaries' companies of London and Dublin have, in like manner, risen from corporations of drug-compounders and unlicensed practitioners across the counter, to be the examiners (virtually) of the great body of medical practitioners of the people. On the other hand, the physicians gradually lost their catholic character by refusing to perform the humbler services of the art, and by discountenancing the practice of them as ignominious. They have thus been as gradually changed into specialists themselves, with the effect of weakening their own influence, and retarding the progress of medicine. Hence, while the corporations of special practitioners have been constantly rising in power and influence in proportion as the principle of unity of medicine has been developed in them, the colleges of physicians and the medical faculties of the universities have been failing in power and influence in proportion as they have departed from that great vital principle. There is hardly a remnant of a medical faculty left in the two great universities of Oxford and Cambridge; while the College of Physicians of London, once so influential, and still in possession of stringent legal powers, is the least powerful of the medical corporations of London. In its palmy days, when it maintained the principle of unity, it could produce an anatomist like Harvey, could give its *imprimatur* to the works of a surgeon like Wiseman, and dictate the pharmacy of the kingdom. In later years, when to be associated in any way with pharmacy, surgery, or obstetrics, was discreditable to a Fellow, and to perform so simple an operation as venesection or vaccination was forbidden by its laws, the college dwindled into a small club of specialists, who weakly surrendered the actual government of the profession in England to a company of London apothecaries.

The medical faculty of the University of Edinburgh, happily for its fame and prosperity, has never abandoned the principle of unity of medical science and art. Candidates for its degree in medicine are required to study all those departments of science a knowledge of which is necessary to the successful cultivation, teaching, and practice of the art. They are also required to give evidence that they possess a competent knowledge of every department under the three heads of Medicine, Surgery, and Midwifery.

SECTION V.—THE FUTURE PROGRESS AND DEVELOPMENT OF MEDICINE.

The future of medicine.

Such, then, has been the past, and such briefly is the present condition of medicine. What will be its future condition? Two elements, external to medicine, will materially influence its future progress for good or evil: the one is the religious belief and condition of the people; the other the wealth and civilization. As to the former, human physiology is become in modern times what, in truth, the phrase designates—the science of human nature; and medicine the practical application of it. The advance of medicine in this direction is bringing it into collision with theological philosophy. We have seen how strenuously this has aforetime resisted the progress of natural philosophy, and we know how much discussion the entrance into its domain of geology and natural history has excited; what, then, will happen when a psychology, springing out of natural history and human physiology, confronts, not corrupt traditions only, but dogmatic and speculative philosophy, especially as applied to theology? Will the old ties of society resist its progress in the old world to its decay? and are we to look to the young states of the Western Hemisphere for unfettered freedom of discussion? or will a new reformation break forth in Europe, and herald a new era in religion, philosophy, and therewith in the medical sciences? Whichever of these may happen it may not be possible to divine; but few thinking men doubt that a great conflict of opinion is impending, if it be not already begun.

If we examine the condition of society more minutely with reference to these phases of development which we have traced as repeatedly occurring in successive epochs, we shall find that different parts of the world are in different stages of progress. It is necessary, therefore, to examine them in relation to each other.

In Western Europe the sacerdotal power has risen from its suppression at the beginning of the century, and is as busily as ever engaged in its old conflict with its old antagonist from all time—the spirit of free inquiry and free expression of opinion. Its success varies on different parts of the field of battle.

In the United Kingdom the event is yet hanging in the balance, and it is doubtful whether it will advance farther, or be made to recoil. The historical parallel of our age and nation is to be found in the age of the old Greek and the mediæval Italian republics. A widely-extended commerce is rapidly accumulating wealth; wealth is developing every branch of science and art. The national power and prosperity are continually increasing in every direction. This is the material side. On the religious and philosophical side there are both retrocession and progress. The sacerdotal power is seeking by all available means to resuscitate its glories of the mediæval age of Europe; while philosophy, whether natural or mental, is questioning the fundamental dogmas of the whole superstructure, but especially those branches included under geology, ethnology, and mental physiology.

In France freedom of opinion sleeps; the military power reigns, but leans upon the sacerdotal power, which it protects. All history shows that that state of society never continues. In which direction will the edifice fall? Upon that the fate of medical science in France depends.

In Central and Southern Europe the military power, and therewith the sacerdotal, is more supreme than in France. Change here is also inevitable, but its character may more easily be anticipated. The sacerdotal power is more dominant than in France—more antagonistic to science—more hated. The scientific element is feeble, but more popular; the military power will therefore probably lean to the latter, and support science and art.

In Eastern Europe the social condition is Asiatic; that is, almost purely patriarchal and sacerdotal. From that region a military sacerdotal power may fall upon Western Europe whenever the nations are torn by discordant religious factions, and success may be hoped for from the weakness of disunion; or that empire may itself fall a prey to civil discord, and be dismembered under military chiefs.

To the Turkish empire the last stage of decrepitude has come; but signs of reconstruction already appear; and if the enterprise and energy of commercial Europe again pour into it, as appears probable, Greek civilization will spring up once again in Asia Minor, and flourish amid the light of Christianity more vigorously than ever.

In Hindustan medicine is even now lifting its head; and the vivifying power of British freedom may happily restore to Asia more than its pristine greatness in science and literature.

On the American continent, and in the colonial empire of Britain, medicine will probably follow the fate of science in the mother country.

It will be seen at least from all this, that medicine, as the science and art of human nature, is of profound interest to the philosophic statesman. Looking at philosophy and religion from the medical point of view, he may also recognise in the present time one of those great eras in which a conflict of opinion shakes society to its foundations, and perils its very existence.

There are cheering indications that the practical English mind will compromise the quarrel, and philosophy and religion be once again combined for the welfare of man. On the one hand, science seeks in many ways to develope religious truth; on the other, not a few of the clergy are meeting science half-way. If by such a compromise all that is corrupt and traditional in Christianity be weeded out, and all that is true and practical in philosophy let in, we may anticipate the commencement of a new era of civilization.

But to this end it is necessary that the human mind be trained from childhood to a free use of its powers, and the great mass of the people be so enlightened as to be able to judge what is true or false, especially in relation to the nature of man. If a wise government could, single-handed, save a nation of ignorant and superstitious people, Marcus Aurelius, the patron of Galen, would have saved the Roman empire. Scientific truth must be amongst the people if it is to save the people.

The organization of the medical profession as students of human nature, and as the men who apply the science of human nature to the wants of mankind, is therefore a problem worthy the consideration of the philosophic and far-seeing statesman. Obscure as they may appear to the superficial observer, and contemptible as they are in the eyes of the mere man of the hour, medical science and the medical profession are working out great changes in the social condition of mankind, and not the less powerfully because silently and imperceptibly. Thus it is, indeed, that all great forces operate, whether in the physical or moral world; else a few fishermen could not have overthrown empires. The revealed action of a force consists often rather in the manifestation of its results than of its working.

The statesman who should succeed in so organizing medicine in all its departments as to give it a full and free application to the wants of society, and in aid of human progress, would surely take rank with the greatest benefactors of mankind. To the attainment of this object it is, however, of all things a primary necessity that a knowledge of human physiology,—that is, of the science of human nature,—be thoroughly diffused through every class of society. This knowledge is indeed necessary to the solution of all social questions; so true it is that "the proper study of mankind is man." (T. L.)

MEDINA, or El Medinah, a city of Arabia, in the province of El Hejaz, is situated in a wide plain forming part of the central plateau of Arabia, about 100 miles N.E. of Yambu, its port on the Red Sea, and about 260 N. of Mecca; N. Lat. 25. 15.; E. Long. 39. 30. Medina consists of a town, a castle, and a suburb nearly as large as the town. The main body of the town is of an irregular oval shape, and is surrounded by walls, built of granite and basalt, in a regular and substantial manner. Entrance is afforded by four gates, two of which, the *Bab el Misri*, or Egyptian Gate, on the W., and the *Bab el Jumah*, or Friday Gate, on the E., consist of large strong buildings, with double towers painted with broad stripes of red, yellow, and other colours. Along the walls, at short distances, there are placed smaller semicircular towers for the additional security of the city. The streets are irregular, narrow, dark, and unpaved, being covered with a soil consisting of hard, black earth. The houses are well built of a basaltic stone, and are generally two storeys high, with flat roofs. Those of the better sort are provided with a large open courtyard, where trees and water basins are frequently seen. The houses have latticed balconies, like those of most eastern towns; and the windows are extremely small. The number of the houses in the town and suburb is believed to amount to 1300, of which there are a few in a ruinous state. The castle, which is situated at the N.W. corner of the city, on a rock, is built like the walls and towers of the city, but in a stronger and more substantial manner. Its entrance is from the E. It is well provided with artillery, ammunition, and provisions, and has a garrison of 400; but it could offer no effective resistance to a force with a few guns and shells. To the S. and W. of the town is the suburb, separated from it by a broad road on the S., called the *Darb el Jenazah*, or Road of Biers, and on the W. by a plain called El Munakhah, about three-quarters of a mile in length by 300 yards in breadth. Although more extensive than the town, the suburb has not so many houses, as it is built in a straggling manner, with many open spaces. On the side next the town it is unprotected; but on the other side there is a wall, which is in a very ruinous condition. The houses in the suburb are for the most part arranged round large courtyards; they are low, and inhabited principally by the lower classes, who are employed to a great extent in agriculture. The suburb has several gates leading to the country; but the only one of these that is of any size is that at the W., called Ambari, a bad imitation of one of the gates of Cairo. The only buildings in the suburb worthy of notice are the governor's house, which is a plain building, situated near El Munakhah; and the five mosques, which are all very much alike,—neat stone edifices, surmounted by cupolas and minarets. Medina is especially famous for the Mosque of the Prophet, which is one of the two sanctuaries of Mohammedanism, and regarded by the Moslems as the second of the three most venerable places of worship in the world; the first being the mosque at Mecca, and the third that at Jerusalem. One of the sects of the Mohammedans even give it the precedence over Mecca, as being the place of burial of Mohammed; while others, on the contrary, do not approve of the high honour that is bestowed upon it by the generality of Mohammedans. The Mosque of Medina is an oblong building, about 420 feet long by 340 broad; and a great part of it, as is usual in Mohammedan mosques, is open to the sky. It is entered by five gates; and has five minarets, which, though not destitute of beauty and grandeur, have little regularity or uniformity. The open part of the mosque is surrounded by a colonnade; of which the northern side is unfinished, and will consist of granite columns and a pavement of marble. On the eastern side there are three rows of columns; on the western four; and the southern side has a much deeper colonnade, consisting of larger columns, and inclosing the tomb of the prophet. The columns of the mosque are very various in form and style, and are not distinguished by any architectural beauty or merit. In the centre of the open court there is a small square piece of ground inclosed by a wooden railing. This is called the Garden of Fatimah, the prophet's daughter, and it contains twelve date trees, of the fruit of which presents are sent to the sultan. To the S.E. of this inclosure stands the Well of the Prophet, supposed by some to have an underground communication with the Zem-Zem at Mecca; although by the majority of Moslem writers it is not held in much veneration, nor esteemed as a holy well. In the covered part of this mosque stands the Hujrah, which contains the tomb of Mohammed, and those of Abubekr and Omar, the first two caliphs. They lie with the heads pointing W. and the feet E., the head of each being opposite to the shoulders of the one immediately in front. These tombs are concealed from sight by a curtain of silk, which is renewed whenever it falls into decay, and upon the accession of a new sultan. It bears inscriptions in gold characters, to the effect that this is the tomb of the prophet and of the first two caliphs; and the position of Mohammed's grave is marked by a large rosary of pearls. Of the tomb of the prophet itself the accounts are very various; and as no one is allowed to approach it on account of the blinding light said to be emitted from it, the descriptions are not much to be relied upon. The popular account of the coffin being suspended

Medina del Campo.

between heaven and earth is a tale which is confined to foreigners, and has probably arisen either from the rude drawings of the mosque, or from a confusion between this and the rock said to be thus suspended in the mosque of Omar at Jerusalem. To the N. of these tombs is that of Fatimah, who is, however, supposed by many to be buried not here, but in the Bakia cemetery. Notwithstanding the universal tradition of the Moslems, it seems very doubtful whether Mohammed be really buried here at all, not only from the extreme discrepancy of the accounts given of the tomb by the learned, but from the great probability that the fable of the miraculous light surrounding it has been invented for the purpose of preventing any inquisitive visitor from prying too closely into the defects of the place. The mosque of Medina has been built and rebuilt six times at different periods; this having been rendered necessary by its frequent destruction by various accidents. The last time of its rebuilding was in 1710 A.D., when it was erected nearly in its present form. The establishment connected with the mosque is large. At the head of it stands the principal of the mosque, who has a salary of about L.300 a month. Under him is a deputy, a black eunuch, who has a pay of L.50. There is also a treasurer and sub-treasurer; besides a chief of the writers and an assistant, who keep the accounts of the mosque. There are also about 120 eunuchs who are under three *shaykhs*, and divided into three orders. Of these, the first act as doorkeepers, the second take care of the cleaner parts of the building, and the third clean the remaining parts, and prevent people from sleeping in the mosque. They get from L.2 to L.5 a month, besides the gratuities they may receive from visitors; and they are in general much respected. There are also a number of free servants, taken from the lower orders of the citizens, who are employed, in parties of 30 each, for a week, and have not much to do. There is also a *kazi* or judge, sent annually from Constantinople, who has under him three *muftis;* and the various other ministers of the mosque are very numerous. In the neighbourhood of Medina is El Bakia, the burial-place of the saints, of an irregular oblong form, inclosed by walls, and surrounded by plantations of palms. In the interior, however, there are no trees or flowers; and the buildings are simple, and by no means remarkable. The inhabitants of Medina are exempt from the payment of taxes, for the attendants of the mosque are paid partly by the sultan, and partly from the rents of the lands in different parts of the world which have been bequeathed to the sanctuary. A certain allowance is also given at Constantinople to any of the inhabitants of this city who may wish to travel. Commerce, however, is little carried on here; and the principal articles are grain, cloth, and provisions. In character the people of Medina are proud and indolent, looking down upon all strangers, and considering labour to be unfit for all but slaves. The climate of Medina is in winter comparatively severe; but in summer the heat is great, though not so oppressive as at Mecca. Throughout the winter rain falls frequently and in great abundance, so that the plain between the city and the suburb is at that season generally covered with water. Pop. from 16,000 to 18,000.

MEDINA DEL CAMPO, a town of Spain, in the province and 28 miles distant from the city of Valladolid, is situated in a plain on the left bank of the River Zapardiel, here crossed by two stone bridges. The partido is crossed by the high road between Madrid and Galicia, and that between Valladolid and Salamanca. The town is well built, and contains, besides remains of ancient convents, a collegiate church and six parish churches, two primary schools, and two hospitals,—the principal or general hospital, a spacious and handsome edifice. On the E. of the town is the celebrated Castilla de la Mota, still subsisting almost entire. The surrounding country produces wheat, barley, and wine; the latter, especially the white, of superior quality. There are also good pastures, which rear sheep, asses, and mules. The population is mostly agricultural, but there are manufactures of chocolate, earthenware, hats, and some other articles. Grain and wine are exported. The population amounted in 1848 to 2760.

Medina del Rio Seco ‖ Mediolanum.

MEDINA DEL RIO SECO, a town of Spain, in the province of Valladolid, from the city of which name it is distant about 24 miles, is situated on two eminences on the right bank of the Sequillo, here crossed by six bridges. The town was formerly surrounded by a strong wall, of which only remain three bastions and the six gates of the city; in the environs are several shaded walks (*alamedas*) much frequented. There are three parish churches: that of Santa Maria, an elegant Gothic edifice, Santiago and Santa Cruz, of Grecian architecture; two convents of Franciscan and Carmelite nuns, and five ex-convents,—that of St Francis being remarkable for the exquisite wood-carvings which it contains. The educational institutions are numerous; besides private establishments, there are two public schools of primary instruction, and two grammar schools. There are two general hospitals well endowed; also a foundling and a maternity hospital. Of the surrounding district, the low-lying lands are very fertile, the chief productions being grain, wine, and legumes of various kinds. The principal manufactures are of watches, locks, and smithwork in general; leather, and cloths of various kinds, especially baize, are also fabricated. The flour and bread of the town and district has a reputation in Spain. Formerly this town was a place of much importance in the internal commerce of the country, and its trade is still considerable. The baize of Siguenza is imported, dyed, and exported; and from various quarters come other articles of manufacture as to a common market. Its two annual fairs, on the 6th of April and 18th of September, were formerly celebrated. Pop. (1848) 4500.

MEDINA SIDONIA, a town of Spain, in the province and 21 miles from the town of Cadiz, is situated at an elevation of about 3000 feet above sea-level, in the form of an amphitheatre, on a spacious hill in the midst of a plain about 4 leagues in circumference. The town is well built, and the streets well paved and commodious. It has two parish churches; the one, Sta. Maria la Coronada, is a handsome Gothic building; that of Santiago is not so attractive. There exist two convents of nuns and five of monks. Of the ten schools in the town, four are public schools of primary instruction. There are two hospitals for the sick, and orphan and foundling hospitals. The surrounding district is traversed by the small rivers Alamo and Barbate, and contains also a number of small lakes or *lagunas*, and several mineral springs. From the mountainous nature of the country, there is more pasture than arable land. Much excellent fruit is grown. There are various brick and pottery works; coarse cloth is also manufactured to some extent. Pop. (1848) of town and district, 10,534.

MEDIOLANUM (*Milan*), the capital of Cisalpine Gaul, stood in the centre of the great plain of Northern Italy, at an equal distance between the Ticinus (*Ticino*) on the W., and the Addua (*Adda*) on the E. According to Livy, it was founded in the territory of the Insubres by the migratory Gallic hordes that crossed the Alps in the reign of Tarquinius Priscus. It was named after a village in Transalpine Gaul. Although the capital of the Insubres, Mediolanum does not seem to have passed beyond the condition of a village until it became subject to the Romans about 190 B.C. Then its pleasant site, in the middle of a large fertile plain, recommended it as a place of residence, and gradually raised it to importance. Strabo calls it "a considerable city;" and in the time of Pliny the Younger it had become a favourite seat of learning. During the wars with the barbarians of Pannonia, Germany, and Gaul, it was often the head-quarters of the Roman emperors. At length Mediolanum attained its highest prosperity when Maximian, about 303 A.D., chose it for his place of residence. It then became the abode of a refined and pleasure-seeking society. Temples, baths, elegant mansions, a palace, a theatre, a circus, and a mint, were speedily erected. It was now the capital of Northern Italy, and was thought worthy by Antonius, a poet of the fourth century, to hold the sixth place among his fourteen "Illustrious Cities." Mediolanum continued to be the seat of the imperial court until Honorius, alarmed at the approach of the Visigoths under Alaric, repaired, about 403 A.D., to the impregnable fortress of Ravenna. Its prosperity then began to decline, and was almost extinguished by the pillaging it suffered from Attila A.D. 452. However, it was still considered the capital of Northern Italy; and in 476 A.D. became the seat of the Gothic kings. Wrested from the Goths soon afterwards by Belisarius, it was retaken and reduced to ashes A.D. 539; yet it regained its prosperity in the middle ages, and retains it to the present day.

MEDITERRANEAN SEA (*Mare Internum*), the great inland sea which separates Europe from Africa, and washes the shores of the three continents of the old world, extends from the Straits of Gibraltar, where it communicates with the Atlantic, to the coast of Syria, and lies between 30. and 46. N. Lat., and between 6. W. and 36. E. Long., having a total length of about 2300 miles, and a breadth varying from 1100 or 1200 to about 80 between Cape Bon and Sicily, supposing the latter to be a part of the European continent. The modern name of the sea, derived from its land-locked position, was not used by the ancients. The Romans called it *Mare Internum* or *Mare Nostrum*, and its various parts had separate names, such as the Ægean, the Ionian, &c. By the Arabians it was known as *Bahr-Rúm*, or the Roman Sea. In the present day it is known to British sailors as the Straits; and the modern Greeks designate it the White Sea, in contrast to the Black Sea. The shores of the Mediterranean are as varied in character and outline as the countries which it washes. At its entrance stands the steep and lofty rock of Gibraltar on the European side, and that of Ceuta on the African, forming the pillars of Hercules, so famous in the ancient classics. The Spanish coast is low and fertile, with a great variety of mountains and plains in the background. It is irregular in outline, and has numerous harbours. Between France and Spain, the Pyrenees, with their high peaks, extend as far as the sea, and terminate in the bold headlands of Capes Norfeo and Creux. The coast of France is low, flat, and marshy, bearing marks of the sea having retreated considerably; but from the Bay of Hyères eastward it is of a more elevated nature. This character is continued along the shore of the Gulf of Genoa, where the sea is bounded by a steep, rocky coast, backed by the lofty mountains of the Apennines, among the recesses of which lie numerous fertile valleys. Very different in character is the W. coast of Italy, from Tuscany southwards to the confines of Naples. The whole of this region, which is known by the name of Maremma, consists of low pestilential swamps, terminating with the Pontine Marshes. The coast of Naples is remarkable for the beauty of its scenery, presenting a bold appearance and an outline much indented with gulfs and bays. To the E. of the Italian Peninsula, the Adriatic, an arm of the Mediterranean, stretches deep into the continent, and its two coasts present a remarkable contrast in nature and aspect. The western shore is low and shelving, with few harbours; while the eastern is bold and rocky, skirted with numerous islands, and containing many safe and excellent stations for anchorage. The coast of Albania, from Valona southwards, is skirted by the rugged and lofty range called Khemára, the Acroceraunian Mountains, so much dreaded by the ancient seamen. The classic shores of Greece, which are washed by the Mediterranean, present an irregular outline, with numerous mountain ridges descending to the sea, and forming large bays, behind which lie fertile valleys retiring among the mountains. The E. coast of Thessaly is skirted by the three famous mountains, Pelion, Ossa, and Olympus; and the N. and E. shores of the Archipelago present in general a bold and irregular outline. The N. shore of the Levant has also many bays and harbours; and, not far inland, rise lofty mountains, forming part of the snowy range of Taurus. The Syrian coast presents a very varied appearance, being in some places mountainous, but in others low and flat. The Egyptian coast is low and sandy; and a similar tract of country extends along the African shore of the Mediterranean as far as Raser-Tyn, where there is a mountainous district containing the site of the ancient *Cyrene*. Further to the W. are situated the Syrtes, which, though a source of terror to the ancients, have been ascertained by modern investigators to be by no means so difficult and dangerous of navigation as had been supposed. The coasts of Tunis are fertile and well cultivated, with numerous bays and harbours; and that of Algeria is remarkable for the beauty of its scenery and the fertility of its soil. The same general character belongs to the coast of Morocco, which extends from the borders of Algeria past the Straits of Gibraltar. A remarkable contrast is observable between the European and African shores of the Mediterranean; the former being irregular and much indented, whereas the latter are comparatively straight and uniform. The same difference, however, may be observed in general between the outlines of the two continents; and to this we may ascribe in some measure their different destinies, and the higher degree of civilization that has been attained by the European nations. The Mediterranean contains a great number of islands, of which the largest, arranged in the order of their size, are Sicily, Sardinia, Crete, Cyprus, Negropont (the ancient *Eubœa*), and Corsica; besides many of smaller size, lying singly or in groups, such as the Balearic, the Ionian islands, and those of the Archipelago. In several parts of the Mediterranean shores there are proofs of a change in the coast-line; and it has been a favourite theory that this sea, formerly a great lake, was brought into its present condition by the bursting of the barrier at Gibraltar from a violent rush of water either from E. or W. This opinion, however, has no greater authority than is due to a mere conjecture of more or less probability. The Mediterranean is divided into two well-marked basins. The western extends from Gibraltar to the narrow channel between Sicily and Tunis; while the eastern, comprising the Levant basin, with the Adriatic and Archipelago, extends from the coast of Tunis to that of Syria and Turkey in Europe, and is about twice the size of the other. Altogether, its area may amount to about 800,000 square miles. Its depth is in general very great, and in many parts as yet unfathomed; but between the E. and W. basins there is a remarkable belt of shallow water, showing that there is a sort of submarine elevation in this part between Europe and Africa. Soundings of no great depth were obtained all the way from Sicily to Tunis by Admiral Smyth; and the Adventure Bank, discovered by that navigator, forms a marked feature of this region, along with the Skerki Rocks, probably the same as those mentioned by Virgil as "saxa latentia:"—

> "Saxa, vocant Itali mediis quæ in fluctibus Aras."

In regard to the water of the Mediterranean there are several circumstances worthy of notice. It has been concluded, both from chemical analysis and from the observed facility with which salt is obtained from it, that the proportion of saline ingredients is greater here than in the ocean; and the ratio between the quantity of salt in the Mediterranean and the Atlantic respectively has been determined by M. Bouillon la Grange, after a series of experiments, to be 41 to 38. The phosphorescent brilliance of this sea is now known to be produced by noctilucous animalcula, but it is not peculiar to the Mediterranean. The prevailing colour of the water is a deep blue; but in the Adriatic it is of a greenish hue, and towards the E. it approaches purple.

The Mediterranean receives many large rivers both from Europe and Africa, of which the most considerable are the Ebro, Rhone, Po, and Nile. And, in addition to the rivers by which it is fed, it derives a considerable supply of water from the strong current which always sets in from the Black Sea and the Sea of Marmora through the Dardanelles, and also from the current which sets in from the Atlantic through the Straits of Gibraltar. But as its level continues unchanged, it would seem that the water entering it is not more than sufficient to supply the waste occasioned by evaporation. Some indeed have supposed that there is an under-current setting outward through the Straits of Gibraltar; but this opinion does not seem to rest on solid and trustworthy evidence. A calculation made by Halley of the quantity of water removed by evaporation showed it to be sufficiently great to preserve the level; but, according to Smyth, the grounds for this theory are insufficient and incorrect. But, however it may be accounted for, there can be no doubt of the fact, that the system of compensation is accurately adjusted between the water coming in and going out. The principal current of the Mediterranean flows to the E., from the Atlantic, along the African coast, till it reaches the coast of Syria and Asia Minor, when it returns westward along the northern shores of the sea. In the middle of the Mediterranean, between Sicily and Africa, the currents are very irregular, varying according to the changes of the wind and weather. In the Adriatic the current runs up the Dalmatian and down the Italian shore with considerable steadiness. In the Archipelago the prevailing direction is from the N.E., caused by the water of the "Pontic Sea"—

> "Whose icy current and compulsive course
> Ne'er feels retiring ebb, but keeps due on
> To the Propontis and the Hellespont."

The Mediterranean is subject to tides, though these are very inconsiderable in comparison with other seas, and very irregular in their motions. This fact, however, cannot be taken as any objection against the true theory of tides discovered by Newton; the weakness of those in this sea being a necessary consequence of its comparatively small extent, and of the narrowness and position of its communication with the ocean, which render it impossible for the level at any part to be considerably raised by the influx of water through a passage which is narrow and in a direction opposite to the course of the great tidal wave of the world.

The prevailing winds in the Mediterranean are those which blow from N. and W.; but in the spring months S.E. and S.W. breezes are most frequent. Among the most remarkable winds in this sea is the *mistral*, a cold wind which comes from the snows of the Alps, and rushes southward, over Provence and the valley of the Rhone, to the sea, blowing with great violence and impetuosity, and forming one of the scourges of Provence. Of a very different character is the much-dreaded *scirocco*, a hot wind blowing from the S.E. over the sultry deserts of Africa. This blast is felt on the S. coast of Sicily; but having passed over a large extent of water, it is not so oppressive there as when it has again become heated by traversing the island; and it is especially felt at Palermo on the N. coast. Another wind, very dangerous to ships, is the *bora;* which, like the ancient *boreas,* whence it derives its name, is a N. or N.E. breeze. It is frequently accompanied with thunder, lightning, and rain; and sometimes lasts as long as three days, though its usual duration is fifteen or twenty hours. Water-spouts are of frequent occurrence in the Mediterranean, and are much dreaded or at least carefully avoided, by cautious navigators. They are believed to be the result of the rotatory motion produced in the atmosphere by whirlwinds, with the addition of the electricity of the air. Electrical phenomena are common in this sea; and one of the most remarkable and famous of these appearances consists of the balls of fire which play round the masts and rigging of ships, called by the ancients *Castor and Pollux*, and by the modern seamen of the Mediterranean, *Corpo Santo*, or *St Elmo's fire*. These meteors are harmless; but when only a single ball appears it is believed to be a bad omen. (See *The Mediterranean; A Memoir, Physical, Historical, and Nautical,* by Rear-Admiral William Henry Smyth, K.S.F., D.C.L., London, 1854.)

The Mediterranean is the theatre of a very extensive trade. Many large commercial cities, such as Barcelona, Marseilles, Genoa, Leghorn, Naples, Palermo, Venice, Trieste, Syra, Smyrna, Alexandria, and perhaps we may add Constantinople, are built on its shores; and there can be no doubt that its trade will increase with the increasing civilization of the extensive countries round the Black Sea and its eastern shore, and the opening (which cannot be long delayed) of the old route to India through Egypt. In the meantime we take leave to subjoin, in illustration of what has now been stated, the following account of the exports from Great Britain to the Mediterranean previously to the interruption occasioned by the Russian war, and in 1856:—

Account of the Declared Value of the Exports of British Produce and Manufactures to the several Countries and Territories (exclusive of France and Spain) bordering on the Mediterranean and Black Sea, in the years 1849, 1850, *and* 1856.

	1849.	1850.	1856.
	L.	L.	L.
The Sardinian territories......	740,806	774,512	1,143,689
Tuscany	777,273	769,409	736,538
The Papal territories	202,518	222,559	311,114
Naples and Sicily	1,115,260	1,026,456	1,202,183
Austrian territories on the Adriatic	658,992	607,755	968,145
Malta	387,744	314,386	541,097
Ionian Islands	165,805	135,912	351,344
Greece	288,847	202,228	261,777
The Turkish dominions, exclusive of Wallachia, Moldavia, Syria, and Egypt...	2,373,669	2,515,821	4,416,029
Wallachia and Moldavia	218,577	294,604	142,964
The Russian ports on the Black Sea	186,996	157,111	148,695
Syria	338,366	303,254	757,774
Egypt	638,411	648,801	1,587,682
Tunis	3,228	5,128	4,093
Algeria	12,551	15,069	20,233
Morocco.........................	65,101	31,799	131,042
Aggregate value......	8,174,144	8,024,804	12,724,399

The Mediterranean is interesting, not only from its geographical and physical character, but from the associations which connect it with the history, and the influence which it has exerted on the trade, condition, and prosperity of mankind in general, and especially of the nations situated along its shores. Adam Smith has shown how well it was fitted to promote the early commerce and navigation of the ancient world; while the riches and prosperity of the nations by whom it was navigated, and their intercourse with each other, increased their knowledge and enlarged their minds. Thus the Mediterranean became a most important means of the civilization of the ancients; and even the great development of literature, poetry, and philosophy, for which these nations were distinguished, may be believed to have had some connection with these circumstances, when we remember that the Phœnicians, the earliest commercial people in the world, had the reputation of being the inventors of letters; that the father of verse as well as the father of history in Greece had evidently travelled much on the shores of the Mediterranean; and that the birthplace of Greek philosophy was in the Asiatic colonies, which were distinguished also for trade and seafaring activity. However this may be, it is certain that the most civilized of ancient nations dwelt along the Mediterranean: Egypt, Phœnicia, Greece, Carthage, Rome, each in turn, played their part in history; and if in modern times this sea is no longer the seat of the world's masters, it is partly because new regions and a wider sphere having been opened mankind have quitted this, the cradle as it were of their young energies; and partly also because a great part of the shores of the Mediterranean have been long subject to the blighting and disastrous influence of the Turkish sway.

MEDOC, a district of France, formerly comprised in the old province of Guyenne, and now forming the N.W. portion of the department of Gironde. This district is particularly famous for its claret wines.

MEDUSA, in fabulous history, one of the three Gorgons, and daughter of Phorcys and Ceto. (See GORGONS.)

MEDWAY (the ancient *Vaga*), a river of England, which rises in the S.E. of the county of Surrey, near East Grinstead, flows in a winding N.N.E. direction across the county of Kent, and joins the Thames by a broad estuary at Sheerness. It passes Tunbridge and Maidstone, and becomes at Rochester and Chatham a tidal stream of great depth, spreading out into a broad estuary, and forming an important harbour for the British navy. It is 60 miles in length, for more than 40 of which it is navigable.

MEEANEE, a town of India, situated in the British province of Sinde, on the banks of the Fulailee branch of the Indus, and 6 miles N. of Hyderabad. Here on the 17th February 1843 Sir Charles Napier gained a brilliant victory over a Beloochee force of vast superiority in point of numbers, headed by the ameers of Sinde. The British troops amounted only to 2800 men, with twelve pieces of artillery; that of the enemy consisted of 22,000, with fifteen pieces of artillery. After a close and obstinate engagement for above three hours, during which the Beloochees showed desperate valour, the right of their position was carried by the Anglo-Indian cavalry, and their army totally routed, losing artillery, ammunition, standards, and camp, with considerable stores and some treasure. The British loss amounted to 256 men killed and wounded; that of the enemy was estimated at 5000. Six of the principal ameers surrendered themselves immediately after the battle. Lat. 25. 26., Long. 68. 26.

MEERMAN, GERARD, a learned writer on law, was born at Leyden in 1722, and was early distinguished for his erudition. In 1748 he was nominated pensionary of Rotterdam; and in 1757 he was sent on an embassy to Great Britain. He died at Aix-la-Chapelle in December 1771. The principal works of Gerard Meerman are *Novus Thesaurus Juris Civilis et Canonici*, in 7 vols. folio, 1751-54; and *Origines Typographicæ*, 4to, 1765. In the latter he attempts to prove that his countryman Lawrence Koster was the inventor of the art of printing. To the former an eighth volume was added by his son.

MEERMAN, *Jan*, an eminent Dutch scholar and statesman, was the only son of the subject of the preceding article, and was born at the Hague in 1753. Scarcely was he ten years old when he published, with the aid of his teacher, a translation of the *Marriage Forcé* of Molière. He afterwards studied under Ernesti, at Leipsic, and under Heyne at Göttingen. On his return from a tour through Saxony and Prussia, he repaired to Leyden to finish his studies, and there he received the diploma of Doctor of Laws in 1774. Jan Meerman was a great tourist, and published full accounts of the observations he made during his travels through almost every country in Europe; yet at the same time he had become so conspicuous for his learning and public activity, that on the accession of Louis Bonaparte in 1806 to the throne of Holland, he was appointed director of the fine arts, and minister of public instruction. These offices he discharged with great zeal and success. In 1810, when Holland was incorporated with France, Meerman became count of the empire and senator. In the latter capacity he was a thorough-going supporter of Napoleon. He died at the Hague on the 15th August 1815. Meerman's principal works are,—*Specimen Juris Publici de Solutione Vinculi quod olim fuit inter sacrum Romanum Imperium et Fœderati Belgii res publicas*, 4to, Leyden, 1774; *History of William, Count of Holland, and King of the Romans*, in 5 vols. 8vo, 1783-97; and *An Historical Account of the North and North-East of Europe*, in 6 vols. 8vo, Hague, 1805-6.

MEERUT, a town of Hindustan, and the principal place of the British district of the same name, is situated upon the western bank of the Kalee Nuddee. It has been from ancient times a place of considerable consequence, and is mentioned amongst the early conquests of Mahmoud of Ghizni in the year 1018. In 1399 it was taken and destroyed by Tamerlane. It was afterwards rebuilt; and when this part of the N.W. provinces came into the possession of the British, it was fixed upon as the capital of one of the districts into which the British possessions in the Doab of the Ganges and Jumna were subdivided. In 1809 it was made one of the principal military stations under the Bengal presidency; and more recently the head-quarters of artillery for the same presidency. It has recently (1857) acquired an infamous celebrity as the place where the mutiny of the Bengal army, which spread with fearful rapidity, first broke out. It was here that the men of the 5th regiment of Bengal cavalry suddenly fell upon their officers, and then released 70 of their comrades who had been imprisoned, under sentence of court-martial, for insubordinate conduct. It was here that the first massacre of Europeans, including women and children, took place; and it was from this place that other native infantry regiments, joining the mutinous 5th cavalry, were allowed to escape to Delhi, and, for the first time in the history of British India, to set at defiance the power and authority of the British government. Meerut is 32 miles N.E. from Delhi; Long. 77. 46. E., Lat. 29. 1. N. The district of which this place is the capital lies between Lat. 28. 33. and 29. 17., Long. 77. 12. and 78. 15. It is about 57 miles in length and 48 in breadth, and has an area of 2332 square miles.

MEGALOPOLIS (*Sinano*), the later capital of Arcadia, stood on the River Helisson, in the middle of a spacious plain on the N.W. border of Arcadia. It was founded at the suggestion of Epaminondas in 370 B.C., shortly after the battle of Leuctra, and was intended to be the capital and stronghold of the Arcadian confederation against Sparta. After the lapse of three years it was finished, and was peopled by settlers drawn from forty different towns. Yet, owing to the inadequate number of its inhabitants, the "great city" never attained to the importance that had been expected. On the overthrow of the Theban supremacy it was forced to strengthen itself against Sparta by an alliance with Macedonia. At length, in 222 B.C., it was surprised by the Spartan king, Cleomenes III.; the greater part of its magnificent structures were rased to the ground; some of its inhabitants were put to the sword, and the rest escaped with difficulty to Messene. Soon afterwards, however, the fugitives returned and rebuilt their city. But Megalopolis never recovered its former importance; and in the time of Pausanias it was little else than a field of ruins. It was the birthplace of the great general Philopœmen, and of the historian Polybius.

MEGARA, the chief city of the Grecian state Megaris, was built on the hills about a mile from the shore of the Saronic Gulf. According to the traditions narrated by Pausanias, the town was founded by Car, the son of Phoroneus. In the course of twelve generations Lelex succeeded to the government, and conferred upon the inhabitants the name of Leleges. A subsequent king, Nisus, called the city Nisæa, and gave the same title to the port which he built on the sea-shore. In the same reign, however, the name was changed to Megara, in honour of Megareus, son of Poseidon, who had been summoned from Bœotia to assist Nisus, and had died in the city; but the port-town still continued to be called Nisæa. These accounts, however, have not been shown to be out of the region of mere fable; and the first fact in the early history of Megara is, that it was included within the ancient limits of Attica. During the reign of Codrus it was wrested from the Athenians by the Dorians; and after remaining for some time in subjection to Corinth, it finally asserted its independence. The favourable situation of Megara now speedily raised it to the height of commercial prosperity. The great highway between the Peloponnesus and Northern Greece running through its territory, brought all the traffic of the country within its reach; and its proximity to the Saronic Gulf on the one side and to the Corinthian on the other, gave it facilities for trading both with the East and the West. To what prosperity Megara had attained in the sixth century before the Christian era is shown by the important colonies it planted. It founded Megara Hyblæa in Sicily in 728 B.C., Astacus in Bithynia in 712 B.C., Chalcedon in 674 B.C., Byzantium in 657 B.C., and several others. But as a result of the commercial opulence, the lower classes became the most influential part of the community; and after a severe contest, the Dorian governors were compelled to resign their power to a demagogue, Theagenes. This potentate was expelled about 600 B.C., and a lengthened struggle between the democracy and aristocracy ensued. In 455 B.C. the Athenians, being summoned to the assistance of the Megarians against the Corinthians, built the two long walls connecting Nisæa with Megara. On the outbreak of the Peloponnesian war Megara became an ally of the Spartans. But the Megarians paid dearly for their hostility to Athens. During seven years their fields were annually wasted, their city was besieged, and their port, Nisæa, was blockaded. However, in the eighth year of the war they were relieved by Brasidas the Spartan general, and succeeded in establishing a firm and exclusive oligarchy. After this period the historical notices of Megara are few and unimportant. It was again under a democracy in 357 B.C. It surrendered without a struggle to a Roman army under Metellus; and in the time of Strabo it was a Roman colony. Megara was celebrated for its philosophical school, founded by Eucleides, a disciple of Socrates. It is now an insignificant village, with about 1000 inhabitants.

MEGARIS, a district of ancient Greece, in the northern part of the Isthmus of Corinth, was bounded on the S. by the Saronic Gulf, on the W. by Corinth and the Corinthian Gulf, on the N. by Bœotia, and on the N.E. by Attica. It extended along the coast for about 25 miles; and its extreme breadth was estimated by Strabo to be 120 stadia. With the exception of the "White Plain," in which Megaris stands, the district is crowded with rugged chains of hills. The Geraneian Mountains extend eastward from the shores of the Corinthian Gulf, sending out offshoots through the entire country, and sinking gradually as they approach the Saronic Gulf. Originally Megaris was inhabited by Æolians and Ionians, and formed part of Attica. It subsequently fell under the dominion of the Dorians. As it contained no town of any importance except Megara, the history of that city is the history of the district. (See MEGARA.)

MEHEMET ALI, or MOHAMMED ALI, or MOHAMMAD 'ALEE, Pasha of Egypt, was born in 1769,—rose by military energy to the pashalic of Cairo in 1806,—seized upon Syria in 1830,—but was deprived of it by the sultan in 1840, after the intervention of the European powers, when the pashalic of Egypt was made hereditary in his family. He administered the affairs of Egypt till 1848, and died in 1849, aged eighty years. (For a full account of his career, see the article EGYPT.)

MEHIDPOOR, a town of Hindustan, in one of the outlying possessions of Indore, or the territory belonging to the Holkar family. It is situated on the banks of the River Seepra, and is celebrated as the scene of the decisive victory obtained by the British in 1817 over the army of Holkar, whose power was in consequence effectually and irretrievably overthrown. The loss on the part of the British amounted to 174 killed and 604 wounded; that of the Mahratta chief was estimated at 3000 men. In the treaty of Mundesor, concluded shortly after, Holkar submitted to terms which reduced him to the condition of an insignificant and dependent power. Lat. 23. 30., Long. 75. 40.

MÉHUL, ÉTIENNE HENRI, one of the most remarkable composers of France, was born at Givet, in Ardennes, on the 24th of June 1763. His father was a cook, and destitute of education. Young Méhul's first lessons in music were derived from a poor blind organist of Givet, and such was the boy's aptitude, that, when ten years old, he was appointed organist of the Franciscan church there. In 1775 an able German musician and organist, Wilhelm Hanser, was engaged for the monastery of Lavaldieu, a few miles from Givet, and Méhul became his occasional pupil. In his sixteenth year Méhul was taken to Paris by a military officer, and placed himself under Edelmann, a good musician and harpsichord player. Méhul's attempts at instrumental composition in 1781 did not succeed, and he therefore turned his attention to vocal music, and especially dramatic. The great composer Gluck received him kindly, and gave him advice in his studies. After various delays and disappointments during his efforts for six years to obtain, at the Grand Opera, a representation of his *Alonzo et Cora*, he offered to the Opera Comique his *Euphrosine et Corradin*, which being accepted and performed in 1790, at once fixed his reputation. The critics acknowledged in it great energy of dramatic expression, and a brilliant instrumentation; but objected to a general want of graceful melody, and to heaviness and monotony in the harmony and accompaniments. His opera of *Stratonice* had great success. After several other operas which did not succeed, his *Adrien* appeared, and added much to his fame. He had been appointed one of the four inspectors of the Paris Conservatory, but that office made him feel continually the insufficiency of his early studies, and the falseness of his position. *Timoléon*, *Ariodant*, and *Bion* followed *Stratonice*, with various success. *Epicure* was composed jointly by Méhul and Cherubini; but the superiority of the latter was evident. Méhul's next opera, *L'Irato*, failed. After writing a number of other operas, his health gave way, from an affection of the chest. He composed in all forty-two operas, besides ballet music, and songs for festivals of the republic. After lingering for several years, he died on the 18th of October 1817. Among Méhul's contemporaries and countrymen may be mentioned Dalayrac, Grétry, and Monsigny, as successful and popular operatic composers. Hérold, another French composer of celebrity, was a pupil of Méhul, and died in January 1833. Boieldieu, Halévy, and Auber, have added much to the reputation of the more modern school of French opera composers. (G. F. G.)

MEHWAS, a district of Hindustan, in the province of Gujerat, situated on the S.E. bank of the Nerbudda River. It literally signifies the residence of thieves, which character formerly attached to the inhabitants, who live by plundering their neighbours. Every man who in this turbulent region could muster twenty horseman, considered himself as an independent chief, and set out on a marauding expedition. When the political control over the Mehwas chiefs became vested in the British government, the best provision practicable was made to meet these evils; and as in such a country crimes attended with violence were most to be apprehended, steps were taken for their suppression with a strong hand, and for the introduction of a well-administered system of criminal justice, to which the country was previously a stranger. It was decided that all persons charged with capital offences, such as gang-robbery, or murder, within the territories of these chiefs, should be tried before a court of justice, in which the British resident and three or four chiefs should sit as assessors. This court was established in 1839, and the results, it is stated, have been found satisfactory.

MEIBOM, or MEIBOMIUS, MARC, a learned philologist, was born about 1630, at Tönningen in the duchy of Schleswig. His first work, a collection of seven ancient authors on music, was dedicated to Queen Christina of Sweden, and procured for him an invitation to the court at Stockholm. There he lived for some time in the enjoyment of a pension from his royal patroness. At length, having undertaken, at the request of the queen, to conduct a concert in the manner of the ancient Greeks, he was so much offended at the roars of ridicule and laughter which his fantastic performance elicited from the courtiers, that he left Sweden immediately. He bent his steps towards Denmark, and there Frederick III. appointed him his librarian, and gave him a chair in the university of Upsal. But in a short time some cause of discontent induced Meibom to vacate his offices, and to repair to Holland. His next appointment, the professorship of belles lettres in the university of Amsterdam, was taken from him after the lapse of a year, in consequence of his fastidious aversion to teach the sons of burgomasters. After sojourning in France for some time, he repaired to England in 1674, intent upon publishing a new edition of the Hebrew Bible; but his whimsical emendations on the sacred text met with no approval, and he was compelled to return to Amsterdam without having accomplished his cherished project. Towards the close of his life he was driven to sell a part of his library to supply his necessities. Marc Meibom died at Utrecht in 1711. The following is a list of his works:—*Dialogus de Proportionibus*, folio, Copenhagen, 1655; *Antiquæ Musicæ Auctores Septem*, in 2 vols. 4to, Amsterdam, 1652; *De Veteri Fabrica Triremium*, 4to, Amsterdam, 1671; *Davidis Balmi Duodecim et totidem Sacræ Scripturæ Veteris Testamenti Integra Capita, prisco Hebræo Metro restituta*, folio, Amsterdam, 1698. An edition of the ancient Greek mythologists, 8vo, Amsterdam, 1688, and an edition of the *Lives of the Philosophers*, by Diogenes Laertius, in 2 vols. 4to, Amsterdam, 1692.

MEINERS, CHRISTOPH, a philosopher, historian, and literateur of Germany, was born at Warstadt, near Otterndorf in Hanover, in 1747. Passing from the gymnasium of Bremen, where he left behind him a reputation for extraordinary ardour, he entered the university of Göttingen, where he completed his education, and afterwards received the appointment of professor of philosophy in 1771. Although as a student he despised the lectures of his masters, despite their acknowledged eminence, preferring to study alone and by the aid of books, yet as a professor his influence and success were by no means remarkable. He was subsequently appointed vice-rector of his university, and became one of the most active members of the Royal Society of Göttingen, established a short time before by the illustrious Haller. He received the title of Aulic Counsellor from the Hanoverian government; and had the honour to be appointed by the Emperor Alexander to the delicate mission of selecting professors capable of naturalizing science and letters in the empire of Russia,—a task which Meiners discharged to the entire satisfaction of his imperial patron. He died on the 1st of May 1810. Meiners occupies a higher position as a writer than as a philosopher. The intellectual independence of his earlier years was more apparent than real when he attained to maturity. The success of his writings is chiefly attributable to two causes,—their popular style, and their practical character. His style, besides being very clear and methodical, is characterized by a happy combination of candour and good sense, which pleases the reader and awakens his interest. On meeting with a speculative problem, his first consideration is not how to subject it to a thorough-going analysis, but rather how to discourse about it in an easy, popular manner. He accordingly waged a perpetual war upon the disciples of Leibnitz and Wolf, and the partisans of Kant, denouncing them as unintelligible scholastics and dreaming mystics. Philosophy in the hands of Meiners ceased to deal with the recondite and the abstract; it became an agreeable piece of study, not requiring much thought, and doing no violence, by an abstract terminology, to the taste of the most fastidious. The only genuine philosopher of the eighteenth century he believed to be Rousseau; and he spared no pains in endeavouring to propagate his doctrines and excuse his errors. Meiners laboured to prove, from ancient and modern history, that public prosperity and individual wellbeing are alike inseparable from enlightenment and virtue. His writings exerted considerable influence in Germany, and his views of the physical and moral inferiority of the Negro race used to be triumphantly quoted in the British Parliament by the defenders of the slave trade.

Of the works of Meiners, which were very voluminous, the principal are,—*Historia Doctrinæ de vero Deo*, 1780; *Gesch. des Ursprungs, &c., der Wissenschaften in Griechenland u. Rom.*, 3 Bde., 1781; *Gesch. der Schönen Künste*, 1787; *Gesch. des Verfalls der Sitten, &c.; der Römer*, 1791; *Gesch. der Religionen*, 1806–7; *Untersuchungen über die Denk. u. Willenskräfte*, 1806.

MEININGEN, a town of Central Germany, capital of the duchy of Saxe-Meiningen, is situated on the right bank of the Werra, 33 miles E.N.E. of Fulda. It stands in a valley, surrounded by wooded hills, and is protected by walls and ditches. The old part of the town is not well built; but the newer portion is regular and handsome. The principal building in the town is the palace of the Dukes of Saxe-Meiningen, where they have resided since 1681. This building contains a gallery of paintings and engravings, a museum of natural history, and a large library. Besides this, Meiningen contains the house of assembly for the states of the duchy, three churches, several schools and hospitals, and a theatre. The manufactures of the place consist of woollen and linen stuffs, leather, &c. The town has ten annual fairs, but the trade is not very considerable. Pop. 6451.

MEISSEN, a town of Saxony, circle of Dresden, occupying a picturesque position on the left bank of the Elbe, 15 miles N.W. of Dresden. The town is for the most part ill built, and the streets are narrow and gloomy. The principal building is the cathedral, a fine Gothic edifice, surmounted by a spire adorned with elegant open work, and containing numerous ancient monuments of the ancestors of the Saxon line of princes and others, as well as several pictures by Albert Durer and Cranach, among which are portraits of Luther, his wife, and his friend Frederick, the elector of Saxony. Close to the cathedral is the Princes' chapel; and not far off stands the palace of Albrechtsburg, formerly the residence of the margraves, but now used as a porcelain manufactory, from which the finest articles are produced. On a high rock, near that on which the palace stands, and joined to it by a stone bridge, stands the former convent of St Afra, now used as a school. There are also several hospitals and other charitable and educational institutions in Meissen. The chief branches of industry pursued here are the manufacture of porcelain, employing 500 or 600 hands, and the making of wine. There are also sugar refineries, tanneries, and dyeworks, but they are not of much importance. Pop. 8914.

MEISSNER, Augustus Gottlieb, a popular German writer, was born at Bauzen in Upper Silesia in 1753. After studying three years at Wittenberg, he went to study law at Leipsic; and afterwards held the offices of chancery-clerk and keeper of the archives at Dresden. In 1785 he was appointed professor of æsthetics and classical literature at the university of Prague; and in 1805 became director of the High School at Fulda, where he remained till his death in 1807. In addition to some translations from the dramas of Molière and Destouches, Meissner wrote the operas of *Das Grab des Mufti*, *Der Alchymist*, *Die Schöne Arsene*, which enjoyed a fair degree of popularity; but the work which rendered him a general favourite with the public was his "Sketches" (*Skizzen*, Leipzig, 1778-96), extending to fourteen series, and made up of essays, tales, and dialogues, &c., written with much lively vigour and quaint pleasantry, and displaying subtle powers of observation and clear-sighted sagacity. These pieces, besides charming the readers of light literature in Germany, attracted the notice of foreign readers also, and were translated, in whole or in part, into French, Danish, and Dutch, and into English in Thompson's *German Miscellany*. Meissner followed up the plan of these sketches in his Tales and Dialogues (*Erzählungen u. Dialogen*, 1781-89), which afford very agreeable and often highly instructive reading. Besides being an extensive contributor to a great number of literary journals, Meissner produced a series of romances of a historical and biographical nature, the principal of which are, —*Bianca Capello*, 1785; *Masaniello*, 1785; *Spartacus*, 1792; *Epaminondas*, 1798; *Das Leben des Julius Cäsar*, 1799.

MEKLONG, or Mekhlong, a town of Siam, is situated at the mouth of a river of the same name, 30 miles S.W. of Bankok. It has a harbour for small vessels, and the trade is considerable. Pop. from 10,000 to 13,000.

MEKONG, Menam-kong, or Cambodia, a river of Asia, which is supposed to rise in the Chinese province of Yunnan, near the frontiers of Thibet, and which flows S.E. through a fertile valley till it falls into the Chinese Sea by several mouths. The river is navigable in the province of Yun-nan; and it receives large volumes of water from the neighbouring mountains. In many parts the stream is deep; but in some places it is interrupted by shallows, rocks, and falls. Many flourishing cities are situated on its banks.

MEKRAN, or Mukran, a province of Beloochistan, bounded on the N. by Afghanistan and the province of Sarawan, E. by those of Jhalawan and Lus, S. by the Indian Ocean, and W. by Persia. It lies between 25. and 28. N. Lat., and between 58. and 66. E. Long.; and has a length of 500 miles, a breadth of 200, and an area of 100,000 square miles. The northern part of this district is mountainous, being traversed by two parallel ranges of mountains from E. to W. The most northern of these, which is the highest, is called the Wushutee Mountains; and between the two ridges lies a tract called Punjgoor, of very inferior elevation. The whole of this northern district bears the name of Kohistan, or highlands. The southern part of the province consists of a low, flat country, for the most part barren and destitute of vegetation. Mekran is separated from the adjoining province of Lus, on the E., by a range of hills called the Hara, running from N. to S. From the mountains down to the sea there stretch numerous water-courses, which are the beds of furious torrents in the rainy season, but at other times are quite dry. In this province there are two wet seasons,—one in February and March, when the wind is generally N.W.; and the other from June till August, when the country is visited by the S.W. monsoon. From March till October the weather is extremely warm, especially in the beginning of August, when the heat is so great as to confine the inhabitants to their houses. Along the coast there is hardly any winter at all, though in the highlands the weather from November to February is cool. The country being generally barren, the people are chiefly employed in pastoral pursuits. In some of the valleys a small quantity of corn is raised; in other parts vines are cultivated; and in the hottest places the date palm thrives remarkably, furnishing an important article of food. The trade of this province is inconsiderable, consisting in the exportation of wool, hides, dates, &c.; and the importation of cloth, iron, sugar, &c. Many of the inhabitants of the coast are employed in fishing, and live to a great extent on fish, as their ancestors did in the days of Alexander the Great. Mekran is in a state of great anarchy and confusion, being partly subject to Persia and partly to the Imam of Muscat; while the most powerful tribe, the Narroi Belooches, employ themselves in frequent and rapid forays, carrying off the inhabitants as well as their cattle. Through this province there are two practicable routes for an army from Persia to India,—one through the highlands, about 100 miles from the sea, and the other along the coast. The former, though more difficult of passage, and inaccessible for artillery, is better supplied with water and provisions than the latter, which was that taken by Alexander on his return from India. Pop. estimated at 200,000.

MELA, Pomponius, the earliest Roman writer on geography, flourished in the first century of the Christian era. From the fact that his surname was Mela, and that he was a Spaniard by birth, some have inferred that he was identical with L. Annæus Mela, the son of Seneca the rhetorician; but the only incidents in his life that are known as certain are gleaned from his work. In it we learn that he was born on the shore of the Bay of Algesiras, at a town which various lections have severally rendered *Tingentera* and *Cingentera*. His mention of the town of Cæsar Augusta, and his occasional allusions to Augustus, indicate that he must have lived at some period after that emperor. At the same time the fact that he speaks (iii. 6) of a mighty emperor triumphing on account of the conquest of Britain, renders it almost certain that he lived in the reign of Claudius, the first Roman potentate who can be said to have subdued that island.

The title generally given to the work of Mela is *De Situ Orbis libri iii.* In the introduction the author divides the northern, or known hemisphere, into three parts: Europe, bounded on the S. by the Mediterranean, and on the E. by the River Tanais (*Don*); Africa, bounded on the E. by the Nile, and on the N. by the Mediterranean; and Asia, the remaining portion. Then, commencing at the Pillars of Hercules, and passing along the southern shore of the Mediterranean, he describes Mauritania, Numidia, Africa Proper, Egypt, Arabia, Syria, Phœnicia, Cilicia, Pamphylia, Lycia, Caria, Ionia, Æolis, Bithynia, Paphlagonia, and the other districts along the coast of the Euxine. In the second book he begins at the Tanais (*Don*), and, coasting along the European shore, he describes Scythia, Thrace, Macedonia, Greece, the Peloponnesus, Epirus, Illyricum, Italy, Gallia Narbonensis, and the eastern coast of Spain. He then concludes this book by a description of the Mediterranean islands. The third book is occupied with an account of the western coast of Spain, the western coast of Gaul, the islands of the Northern Ocean, Germany, Sarmatia, the countries on the Caspian Sea, Carmania, Persia, Arabia, Ethiopia, and that part of Mauritania which borders on the Atlantic. In the composition of his work Mela has followed Eratosthenes, and other Greek geographers, with a closeness that sometimes prevents him from availing himself of the fuller and more accurate information of his own day. The text, chiefly on account of the abundance of proper names, is swarming with corruptions. Simplicity, conciseness, and perspicuity are the characteristics of the style. The best editions of Mela are those of Gronovius, 8vo, Leyden, 1728, and Tzschuckius, 8vo, Leipsic, 1807. There is an old English translation, entitled "The rare and singular Work of Pomponius Mela, that excellent and worthy cosmographer, of the situation of the World, most orderly prepared, and divided every parte by its selfe: with the Longitude and Latitude of everie Kingdome, Regent, Province, Rivers, &c., translated in Englyshe by Arthur Golding, Gent, 4to, London, 1590."

MELAMPUS, a famous physician and soothsayer in fabulous history, was the son of Amythæon. His mother is variously represented to have been Eidomene, Aglaia, and Rhodope. While living with his uncle Neleus, King of Pylos, in the Peloponnesus, he happened one day to fall asleep on the grass in front of his house. A brood of young serpents, which he had tamed, crawled upon his head, and began to lick his ears. Wakened by their touch, he started up, and discovered for the first time that he understood the chirping of the birds on the trees, and had thus acquired the means of interpreting the future. About the same time he had an interview with Apollo by the side of the Alpheus (*Rufia*), and was initiated by him into the mysteries of medicine. Melampus had gained great repute as a soothsayer, when his brother Bias fell violently in love with Pero, the daughter of King Neleus. The father, however, declared that no man could win the maiden's hand but he who should carry off the oxen of Iphiclus from Phylace. As that herd was guarded by a huge dog of noted ferocity, Bias did not dare to attempt the feat, but called in the aid of his soothsaying brother. Melampus accordingly proceeded to drive off the oxen, was caught, as he had foreseen, in the attempt, and was thrown into prison. During his confinement he contrived to make known his supernatural gifts, and was asked to prescribe a remedy by which Iphiclus might become a father. The prescription proved successful, and Melampus was presented with the coveted herd as a reward. He was next employed by Anaxagoras, King of Argos, to cure the women in his kingdom of an epidemic frenzy. In consideration of this service he was rewarded with one-third of the territory of Argos for himself, and another for his brother Bias. Instead of this story, however, some relate another. According to them, the three daughters of the Argive King Prœtus were the persons whom Melampus restored to sanity; and in return for his aid the physician received the hand of Iphianassa, or Iphianeira, the eldest of the princesses, and a third part of the territory of her father. By this wife he is said to have had four children,—Antiphates, Manto, Bias, and Pronoe. Melampus was reckoned by the ancients to have been the first prophet, and the first who practised the art of medicine. The medicinal herb μελαμπόδιον (*sneeze-wort*), acquired its name from having been first used by him. He received divine honours after death, and his temple was built at Ægosthena in Megaris. His descendants were a family of prophets.

MELANCTHON, Philip, or Melanthon, as he was accustomed to spell his name towards the close of his life, was born at Bretten, or Bretheim, a town of the Lower Palatinate, 16th Feb. 1497. His father, George Schwarzerde, or Schwarzerd, was a native of Heidelberg, an armourer of some celebrity in his trade, and a kinsman of the famous scholar Reuchlin. He was a man pious and affectionate, but at the same time stern and unflinching; and his calm, truthful nature seems to have been deepened into a grave and gloomy earnestness by the continued rankling of a sickness begun four years before his death, and by his friends attributed to an accidental draught of slow poison. On his deathbed he committed his son, then a boy of eleven years, to God's guidance, in prospect of "terrible tempests that were about to shake the world." Melancthon's mother, Barbara Reuter, was a daughter of a distinguished citizen of Bretten, who had for some years been mayor of the town. What her husband was from principle she was by instinct; and with her instinctive love of truth and charity there mingled an idealizing grace which seems to have bordered on superstition. She was the author of the popular housewifely rhyme, beginning

"Almosen geben armet nicht."[1]

She was passionately fond of young Philip, and remained a widow until the tie which bound them together was loosened, not without many misgivings on her part, by his marriage. On account of the armourer's incessant occupations, the early education of her favourite boy fell into her hands; but she was assisted by her father, and Reuchlin, her husband's kinsman, seems to have taken great interest in his progress. In approbation of Philip's boyish acquirements this devoted scholar sent him a present of two books, a Greek grammar and a Bible; and it is interesting to note that thus early his talents were turned into their destined channel, Greek literature and sacred learning. At a school at Pfortsheim, where George Simler was rector, Philip received his classical education. He lived, along with John Reuter, in the house of Reuchlin's sister, and was thus frequently brought into familiar intercourse with the rugged author of the *Epistolæ Obscurorum Virorum.* From Reuchlin, who had allowed himself to be dubbed "Capnio" (*Kapnos* being the Greek of *Rauch*, smoke), the young Schwarzerde (black earth) received the Grecized name of Melancthon, by which he is now universally known. In 1509 he was sent to the university of Heidelberg; and in 1512 he removed to Tübingen, where he acquired so great a reputation for scholarship as to deserve a high encomium from Erasmus, who predicted that himself and all the other lights of learning would soon be eclipsed by this stripling of eighteen. In the beginning of 1514 Melancthon received his doctorship in philosophy. He immediately began to give public lectures in rhetoric, and to expound Virgil and Terence and other authors. Of his inner history, as he was now approaching the crisis of his life, we can obtain only a passing glance. At a later period he tells us how he shuddered at the remembrance of his youthful image-worship; but we know that at this time he was a diligent student of the Scripture, and that as he carried the favourite Bible of Frobenius to the church, the monks, who thought every one a Jew who read Hebrew and every one a heretic who read Greek, did not fail to insinuate the heathenism of reading books of suspicious bulk within the sacred precincts.

He had been thus engaged for three years, when, on the nomination of Reuchlin, he was appointed by the elector of Saxony professor of Greek in the university of Wittemberg. "All Tübingen," says Simler, "lamented his departure;" but when he arrived at Wittemberg, after a journey which was a continued ovation, his slight figure, hesitant expression, and ungraceful gait, created an impression far from favourable. The facility and grace of his inaugural oration, however, quickly dispelled the fears of the professors; and Luther, who had shaken his head with the rest, was among the foremost to celebrate the learning and power of his youthful colleague. Melancthon, on his part, was not slow to appreciate the depth and warmth of Luther's character. A letter is extant, which seems to have been written about this time, in which Melancthon says, that "if he loved any man on earth with his whole heart, that man was Martin." And thus began the intimacy of two friends, destined, with their united strength, to roll the religious as well as the literary world back on its axis, but each leaving the impress of his own human weakness on the machinery which they framed to effect the revolution. "Luther," says D'Aubigne, "possessed warmth, vigour, and strength; Melancthon clearness, discretion, and mildness. Luther gave energy to Melancthon; Melancthon moderated Luther. They were like substances in a state of positive and negative electricity, which mutually act upon each other. If Luther had been without Melancthon, perhaps the torrent would have overflowed its banks. Melancthon, when Luther was taken from him by death, hesitated and gave way, even when he should not have yielded."

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[1] Alms-giving beggareth not:
Church-going hindereth not:
To grease the car delayeth not:
Gain ill-gotten helpeth not:
God's book deceiveth not.
Müller's *Reliquien.*

Under the teaching of Melancthon, Wittemberg became the school of the nation. The scholastic methods of instruction were summarily abandoned; and in a *Discourse on Reforming the Studies of Youth*, which Melancthon gave in the first year of his professorship, the key-note was struck of a deeper earnestness in philology, and of a keener appreciation of truth, felt by minds of fearless truthfulness to be sacred, although buried in the classics of heathen antiquity. During that year his lectures were divided between Homer and the apostle Paul; and it is characteristic of the man that the same devout and reverent spirit guided his studies in both. In reading Homer he announced it as his aim, like Solomon, to seek Tyrian brass and gems for the adornment of God's temple. It is also significant of his tendency to purify where others would destroy, that, though at first carried away by Luther's denunciation of the Peripatetic philosophy, he quickly retracted his opinion, and sought to use the logic of the schools as a wholesome discipline in the service of theology. He was instrumental also, by his advent at Wittemberg, in stimulating and assisting Luther in the translation of the Bible, which was begun as early as 1517, but was progressing somewhat fitfully and slowly. All this happened within the bosom of the Church of Rome, with which his colleague and he were soon to be in open rupture.

Issuing from the patronage of Reuchlin, and deeply imbued with love for the Scriptures, Melancthon adopted without difficulty the principles of Wittemberg. In proof of his earnestness, he attended Luther and Carlstadt to the disputation of Leipsic. He took no public part in the debate, but, by his private suggestions to the combatants, he attracted the angry sarcasms of Eck, who was indignant that this grammarian, as he called him, should dare to interfere in the discussion. On its conclusion, Melancthon addressed an account of the debate in a letter to Œcolampadius; and so lightly did the passions of the time agitate his truthful nature, that this epistle contains no exaggerated eulogies of his own party, and even mentions the general admiration entertained towards Eck on account of his varied talents. Yet that vain polemic professed to be offended at this narrative, and affecting to appreciate the superior erudition of Luther, rejected with scorn the tribute offered by so unworthy a hand.

From this time forward Melancthon devoted himself almost exclusively to theology, and his history becomes so thoroughly interwoven with that of the Reformation, that only those points can be touched in which he stood aloof or alone among the band of Reformers. His life was chiefly spent in writing books, and visiting colleges and churches at the command of the elector. In 1520 he married Catharine Krapp, the daughter of a burgomaster of the town, and by her he had two sons and two daughters, who all survived him. She seems to have been of a very timid disposition. He admired her; was forced often to yield to her entreaties; but he never gave her half the love he gave to his books; and on the marriage-day, conscious of a kind of half-heartedness in the affair, he could not help saying she deserved a better husband. In 1521 he rendered what is his most valuable contribution to theological literature. His *Loci Communes Rerum Theologicarum* were a sort of summary of Christian doctrine, in which the truths asserted by Luther in his various compositions were reduced to a system, and thus more easily inculcated. The subjects of difference with the Romish church are distinctly stated with reference to scriptural proof, and without controversial argument—a method of persuasion better suited to moderate minds than the most eloquent appeals of impassioned reason. It was the opposite to the method of Luther; yet the latter was so sensible of its advantages, and so little bigoted to his own style, that he bestowed the strongest possible eulogy on the production of his friend: he ranked it incomparably above the writings of the fathers, and pronounced it to be the best book he had ever seen except the Bible. That in the heat of contending parties the exposition should be so calm, is a beautiful proof of the natural bent of Melancthon's mind to idealize his antagonists; but this necessity of his nature was all the more perilous for his peace and power, when error threw a veil over its practical extravagances, and became attractive only when impersonal. Thus, when Stubner and Cellarius, escaping from among the raving artizans of Zwickau, forced themselves on the peaceful society of Wittemberg, and gave utterance to their solemn impostures in his presence, the mind of Melancthon was perplexed and shaken. In pensive adoration of the doctrine of heavenly influences, which they put in the forefront of their teaching, he received and protected the men whose whole lives and utterances were a libel on the Spirit's agency. It is even said that he went so far as to advise his scholars to renounce the study of profane literature, and to confine their industry to the reading of the Bible and the practice of mechanical arts. Such power had the simple brightness of delusive doctrine to kindle reverence in his mind. It needed the keen practical instincts of Luther to detect the rent in the skirts of the idol's shining robe, and by a strong hand to expose the human folly and trickery concealed under the mask of mystery before which his companion trembled.

The share which Melancthon had in the transactions of the Diet of Augsburg has been already minutely given in this work under the Life of Luther. He fell under the *italitates* of his enemies at a time when a final blow required to be struck, but when his vision was hemmed in and his spirits oppressed by the dark clouds that overhung the national horizon. He had not the strong faith of Luther either in the warlike mission or the final triumph of truth; and it is no wonder that in such a battlefield the two friends should have parted company. That oppressive love of home, which was a peculiar feature in Melancthon's character, acting on a spirit tuned from boyhood to superstitious reverence, seems to have asserted its sway in this crisis of home-leaving from the Church of Rome; and in the entire absence of a sublime revenge against error and wrong, which is the birthright of the true reformer, there was no passion left in the mind of Melancthon to still the struggles of human tenderness, or break the chains of youthful awe. Besides, his catholic spirit, which had strong yearnings, although no prophetic glimpses, shrunk from the sad necessity of converting forts of defence into armed sanctuaries of solid stone, lest the building of the one temple of God should be delayed till not the tottering walls of Babylon, but the too narrow Jerusalem of the Reformed Church, should crumble into the dust. At all events, those who now inherit his hesitancy profess thus to interpret his spirit. The *Interim* of Augsburg, drawn up by Pflug, Sidonius, and Agricola, with the view of bridging over the chasm between the Roman Church and the Reformed, although it did not receive the approbation of Melancthon, is famous as having called forth the Adiaphoristic controversy, in which Melancthon propounded his views on the obligation of things indifferent to the personal salvation and purity of the believer. This *Interim adultero-Germanum*, as Calvin styled it, contained nearly the entire system of Romish theology; and Melancthon and the Philippists generally addressed themselves to the hopeless task of so modifying its statements as to accommodate them to the views of the Reformers. He was willing to tolerate both a popedom and a hierarchy, stripped, however, of divine right, and deprived of all power in matters of faith. He thought the church should allow seven sacraments, provided the name of sacrament was not given to those rites only of human origin. The relation of faith to works, and the doctrine of the sacraments, might, in his estimation, be veiled in a judicious obscurity of phrase. The contest assumed a new significance after the publication of the Leipsic *Interim* in 1548. In this deed the Philippists defined what those things were which they regarded as indifferent; and in which, for the sake of peace and unity, they thought they might be at liberty to obey the emperor. It must not, however, be forgotten, that from the views given in the *Loci Communes* as the expression of his own faith Melancthon never swerved; and that he regarded the surrender of more perfect for less perfect forms of truth as a painful sacrifice conscientiously rendered to the weakness of erring brethren.

By this time Luther had been two years dead. From their earliest intimacy he had delighted to call himself the forerunner of Philip, and had compared himself to a storm-wind ushering in the still small voice of his friend. The storm-wind, however, did not cease at Luther's death, and in the general confusion the calm voice of Melancthon was scarcely heard. The last years of his life were spent in fruitless conferences with the representatives of Rome on the one hand and the more distinguished Reformers on the other, in somewhat feeble replies to the fierce assaults of his enemies, and in the more pleasant duties of his professional office. How much his mild spirit was depressed by the contention of the times may be gathered from the tone of holy happiness which elevates his correspondence whenever, in his later years, he is called to celebrate the death of a dear friend. During the last three years of his life he suffered much from cold and intermittent fever. His wife died in the end of 1557; and the fatal year when he should be 63 years of age—a term to which he had looked forward with a mysterious dread as that beyond which his mortal existence could not possibly be prolonged—was fast approaching. In 1558 he calmly adjusted the desirability of living or dying; and in the one balance he found nothing but sin and the rage of theologians to be weighed against the light of God's face, the unveiling of the mysteries of providence on earth, and the full intelligence of Christ's nature in heaven. On the 12th April 1560 he delivered his last lecture; and his few moments of strength were spent in writing the *Chronicon*, a narrative of general history from the Creation to the Reformation. On the 19th April of that same year he breathed his last, having lived little more than two months beyond the period which he considered a fatal term. His body was laid in a leaden coffin close beside that of Martin Luther.

Melancthon's Life has been written by Camerarius, and from his biography we draw almost exclusively the details of his private and domestic history. There are, however, more recent sketches of his life and times by Karl Matthes; and by C. F. Ledderhose, Heid. 1847–8. In English there is a somewhat meagre biography by F. A. Cox, London, 1815; but the most enduring monument of his fame is the *Reformatorum Opera*, edited by Bretschneider, but still unfinished, the first 22 vols. of which do not exhaust the works of Melancthon.

MELBOURNE, the capital of the colony of Victoria in South-Eastern Australia, is situated on the River Yarra-Yarra, at the head of the large estuary of Port Phillip, in S. Lat. 37. 48., E. Long. 144. 58. The site was selected and occupied in the year 1835 by a small colonizing party from Van Diemen's Land. The town was officially recognised and designated two years afterwards by the government of New South Wales, to which colony Melbourne, together with the surrounding district, pertained until its formation into an independent colony in 1851 under the present name of Victoria. The capital of the future colony was named in honour of the English prime minister of the day, Lord Melbourne.

The rapid growth of Melbourne has given it an extension far beyond the limits of its original plan. The principal part of the town is still on the northern bank of the river, where it was first founded; but considerable divisions or wards have sprung up on the south side also, where South Melbourne, Sandridge, St Kilda, and the western part of South Yarra, are comprised within the city boundary. On the northern bank the site consists of two eminences, called respectively the Eastern and Western Hills, which, with the intervening hollow, have been overspread with streets and houses. The lower situations along the bank, and for a short distance up this hollow (now the main thoroughfare called Elizabeth Street), were until lately exposed to floods from the river; but the municipal improvements have now so considerably raised these exposed places as to cause little or no apprehension on this account for the future. The southern side of the river is flat and swampy, excepting the sandy margin upon the bay where Sandridge is built, and the rising ground where the other parts of Melbourne already spoken of are laid out. To the westward, on the N. side of the Yarra, is another flat called Batman's Swamp, having a salt lagune, without outlet, and a creek or chain of ponds entering it at the north, but without stream in its bed save on rare occurrences of heavy rains. So much surrounding low land is considered unfavourable to health; and the low parts of the town are decidedly so, especially in the present imperfectly drained condition of Melbourne. The original block of the town was laid out without open reserves, probably from the moderate anticipations of the future city. In the subsequent extension, however, this great defect has been remedied. Besides the Royal Park to the N.W., and the Police Paddock and other large spaces on the outskirts, there are the beautiful natural sites of the Carlton and Fitzroy Gardens, which are already being surrounded by the houses of the expanding capital.

The undulation of the site has occasioned some artificial levelling, although not to a great extent. The streets are mostly at right angles; and being of considerable length, straight, and of ample width, they have a good appearance. All the principal lines are well finished, being macadamized in the middle, and drained, kerbed, and to a great extent flagged, on either side. In the original plan there were alternate lanes or narrow streets, which had been intended to serve as back entrances to allotments extending from the main streets. As the town increased, however, and the lands became very valuable, the original allotments were subdivided to a degree far beyond what had been anticipated, so that those lanes soon became independent streets, and among the busiest hives of population and trade. They are thus an unhealthy feature of the older town; and the mistake has not been repeated with the newer plans.

The climate of Melbourne in its mean results is cooler, as usual in the Southern Hemisphere, than that of the same latitude in the N., but it is subject to very frequent changes, particularly during the summer season. The mean temperature of January last (midsummer), for example, was 66°·4. The highest indicated temperature was 101°·1, the lowest 48°; while the mean daily range of the month was so considerable as 19°·4. It is not, therefore, a climate suited to invalids, as is often supposed. It possesses, however, an agreeableness of character, arising from the great proportion of fair and sunny weather, which is especially noticeable to the British emigrant. Another mistake, still more common, attributes to Australian colonies a very diminished supply of rain as compared with European countries. On this subject the following results are interesting, as they compare the rain-fall at Melbourne with that at London :—At Melbourne the annual mean of five years (1847-51) gave 32·63 inches; while at London the mean of twenty years, ending in 1846, gave only 24·04 inches. The seasons of greatest rain in each are somewhat different. The wettest months at Melbourne were those between April and November inclusive, when the monthly mean was 3·4 inches; while the driest were between December and March, the monthly average being only 1·3 inch. Thus the most rain occurred from the last half of autumn to the beginning of summer; while in London, it would appear, the rain falls proportionably most from midsummer to the beginning of winter (June to November). This is almost an exact reversal; but as the opposites in the antipodean seasons have been allowed for, it follows, that both in London and at its antipodes the greatest proportions of rain are occurring during about the same time.

The commerce of Melbourne has already attained to a scale that constitutes it, so far as regards that test, the principal port of the British colonial dominions and of the Southern Hemisphere. This great and sudden development is due to the Australian gold discoveries that took place in 1851. Although the first discoveries were made in New South Wales, yet Victoria, where the gold was soon after found, has ever since yielded by far the larger proportion; and as nearly all the auriferous wealth flows through Melbourne, that place has thus acquired its surpassing importance.

The following figures represent the import and export commerce of the port of Melbourne for the last two years (1855 and 1856) according to the declared value at the customs :—

	1855.	1856.
Imports	L.10,232,279	L.13,240,751
Exports	12,706,849	14,363,250

Nearly the whole external commerce of the colony has been gradually concentrating in Melbourne. For the year 1855 the total amounts for the colony were,—imports, L.11,568,904; exports, L.13,469,194; from which we observe that Melbourne possesses nearly eight-ninths of the import and sixteen-seventeenths of the export commerce. The export of gold is in the proportion of five-sixths of the whole amount of exports.

The great and yearly expanding importance of Melbourne as a seaport demands for that part of our subject a short notice. The city is 8 miles by river course from the mouth of the Yarra, and thence to the Heads of Port Phillip is 35 miles. These Heads are but 2 miles apart; and through this strait, so narrow as compared with the expanse of Port Phillip, the ebb and flow of the outer ocean sweeps with a strong current of 5 or 6 miles an hour, rendered more remarkable by the eddying and jumbling of the water caused by the great inequality of depth in the channel. Ships sailing inwards are in a few minutes transported from the stormiest to the calmest waters. Each in-flowing tide is charged more or less with sand, sustained while the waters are in motion, but deposited when they have come to rest within the bay. Thus has arisen a system of sandbanks extending 12 miles inwards, and navigable by several channels, the deepest of which, called the South Channel, takes a circuit by the S. and E. of the bay. As the entrance is dangerous, particularly at night, pilots cruise about outside. The danger, however, is now much diminished since a second light has been added to Shortland's Bluff, so as to afford a safe entrance by keeping the two in line.

The anchorage is at Hobson's Bay, the upper part of Port Phillip, where the larger vessels were discharged by means of lighters until within the last two years, when the Melbourne and Hobson's Bay Railway began to expedite this tedious process. The railway from Williamstown, now nearly completed, will be a further improvement; and although considerably longer, it has the advantage of a better sheltered jetty than the other. Extensive wharf accommodation has been recently made at Melbourne to accommodate the fleet of the smaller shipping and the lighters. The authorities, in regard to harbour improvement policy, have been for some time undecided between deepening the present circuitous river-course and opening a new and straight cut to the bay; the first being 8 miles, while the other would be only about 1¾ mile. Opinion now inclines to the first. The river has two bars or shallows,—one at the mouth, the other half-way to Melbourne; and neither has more than nine feet of water at usual flood-tides. Besides these, however, other places, although not so shallow, require to be deepened. Neither scheme can be carried out without heavy expense; still the object to be attained is greatly more important than the consideration of its cost. A patent slip on a large scale is now being erected at Williamstown. The rise and fall of tide in the bay has usually a range of only three feet. Persons interested in shipping and merchandise should be careful, in bills of trading, of the use of the words "Port of Melbourne," which, although intended to mean Melbourne itself, is now usually held to be the anchorage off Williamstown, unless the vessel is destined for or is able to proceed up to "Melbourne Wharf."

Melbourne is the seat of a municipality, which was conferred in the year 1843. The mayor and aldermen are elected by the council. The following is the valuation of the city, taken for the purpose of levying the rate, for the six years ending 1857 :—

1852	L.174,723
1853	638,824
1854	1,553,965
1855	1,077,725
1856	726,807
1857	911,414

The valuation for each year is taken towards the end of the year preceding. We here observe the great rise in value caused by the gold discoveries. Not less striking is the reaction after 1854, when the colonists had gone too great a length. The year 1856 gives less than half the value for 1854, notwithstanding that some extension and improvement had been effected intermediately. As the colony is again actively progressing, the value for 1857 shows a large advance on that of the preceding year. The number of houses for 1857 is given at 10,334, affording the unparalleled average of nearly L.90 of yearly value for each house.

The municipal revenues are considerable. In 1854 they amounted to L.69,938 in gross total, and in 1856 to L.71,717, which last amount comprised L.48,000 of city rate, L.10,000 of lighting rate, and L.8000 of market dues. The expense of salaries for 1856 was L.12,954. In 1854 L.500,000 was borrowed by the corporation under the sanction and with the guarantee of the colonial government. With so effective an aid the town was greatly improved in its streets. Already nearly a million sterling may be computed to have been spent in such improvements.

Melbourne is the seat of the colonial government, which is now, since the recent concession of political freedom, administered on the constitutional plan of that of England. There are two houses of parliament, both elected by the people; while the governor is nominated by the crown. The press is an active agent, and issues three large daily papers in Melbourne, besides various others at longer intervals.

Melbourne already possesses many public institutions of a charitable or useful description. The hospital was begun in 1846; and in 1856 administered to 1725 in-door and 3393 out-door patients. There is also a benevolent and a lunatic asylum, a mechanics' institution and public library, and latterly a spacious and costly university, which as yet, however has not been adequately supplied with pupils. The Parliament-House, which is still unfinished, will be a very large and handsome structure.

The costliness of everything, and the rush and bustle of life and business during the first years of the gold-digging, caused the erection of many poor and temporary structures throughout the town. Many grotesque-looking edifices of wood and iron had been rapidly put up, which contributed little by way of ornament, and still less of comfort under the extremes of the climate. An entire suburb of tents on the southern side of the river acquired the significant name of Canvastown; but it has now happily quite disappeared, and with it much misery and mortality. The iron and timber buildings are gradually being displaced by a better kind of edifice as their sites get more valuable. There are now many handsome shops, and a considerable profusion of plate-glass, which begins to appear in the windows of private residences as well as of numerous shops and warehouses. Many houses of timber or iron still remain; but, with few exceptions, the custom is now to build of brick or stone, particularly of the former, as bricks are now largely made in the country. The various churches, which are chiefly collected upon the Eastern Hill, exhibit amongst them some large and costly edifices. The banking companies, too, have erected handsome places of business; and many substantial warehouses of the merchants are scattered over the town. The river is crossed by a bridge of unusually large span. The chief thoroughfares are crowded with traffic, with foot-passengers and omnibuses, to an extent not inferior to that exhibited by the larger and most stirring of the British towns.

Melbourne boasts of a large "Theatre-Royal," nearly equal in its accommodation to the largest London houses. There are two smaller theatres, and a spacious "Astley's." The last is a wooden fabric, and being capable of containing 4000 persons, it is much used for the political and other "mass meetings" of the colonists. In the suburbs are "Cremorne Gardens," where fireworks, Sebastopol sieges, and other attractions are nightly exhibited. The annual races last for three days, and are always so absorbing as almost to cause a general holiday-making. Cricket, too, is a favourite pastime both in Melbourne and throughout the colony.

In front of the town-hall and adjacent police-office is a considerable stand of cabs. There are regular daily coaches to the interior towns that are rising rapidly upon or near to the different gold-fields; and a growing fleet of steamers maintains regular communications with neighbouring ports and colonies,—namely, daily to Geelong, and at wider intervals to Alberton, Sydney, Portland, Adelaide, Launceston, and Hobart Town. Railway travelling is as yet confined to the two miles of the Melbourne and Hobson's Bay line, and a small part of the Geelong and Melbourne line next the former town; but it is expected that the present year (1857) will witness the opening of the entire way, together with the branch of the Hobson's Bay line to St Kilda, and the line to Williamstown. The great lines to the gold-fields are as yet scarcely commenced.

Among the more recent improvements in the city connected with the sanitary and general wellbeing, we may notice the erection of an elegant and substantial market-place in the Custom-House Square; and in the same locality a savings-bank and a fine exchange edifice for the use of the commercial interests, and a place of meeting for the Chamber of Commerce. In January 1856 Melbourne was lighted with gas. At a latter period of the same year a supply of water was introduced throughout the town, raised from the river by pumping machinery. By this arrangement, besides the supply to the dwellings, there is a regular watering of the streets; while the risk from fire is greatly diminished. This supply, however, is only temporary, pending the completion of the gigantic works connected with the Yan Yean reservoir, near the head of the River Plenty, about 18 miles to the N.E. of the town. Immediately following this completion will come the much-wanted drainage and sewerage, upon which the health of the population of Melbourne so greatly depends.

The increase of the population of Melbourne has been as remarkable as that of its commerce. The census of 1841 gives it 4440; that of 1846 a little short of 10,000. In 1851, just prior to the gold discoveries, it had attained to 23,000; but in 1854 the numbers were 53,235, while the suburbs contained 23,330,—making a total of 76,565.

A census taken on 29th March last (1857), but the results of which have not yet been made public, will probably give to Melbourne about 70,000 within the city boundaries, besides 30,000 in the suburbs, making a total of 100,000 souls.

(W. W—H.)

MELCHISEDEC, (מלכי־צדק, *rex justitiæ*), the name of an individual who occupies an important place amongst the characters which appear in the Old Testament history, as typical of Christ. Very little, however, is said in Scripture regarding him personally; his name occurs only twice in the Old Testament (in Gen. xiv. 18, and in Psalm cx. 4); and the reference to him in the New (in Heb. vii. 20, and vii. 1) has respect only to his typical character. His name is mentioned for the first time in the sacred history on the occasion of the return of Abraham from the defeat of the four kings or sheikhs who had invaded the district of Sodom, and carried captive his nephew Lot. In the valley of Shaveh, or "The King's Dale," probably the same valley as that mentioned under the same name in 2 Samuel xviii. 18, the victor was met by Melchisedec, who is described as "the King of Salem," and who, with the generous readiness of eastern hospitality, set before him and his troop "bread and wine,"—that is, a plentiful repast.[1] Whether the Salem here mentioned is the same as that mentioned in Psalm lxxvi. 2, and which is plainly Jerusalem; or is, as Jerome suggests, a place near Scythopolis, and which he identifies also with the Salem near to which John the Baptist baptized, remains still a matter of dispute among scholars. The majority of eminent names is in favour of the former opinion; but Bochart, Rosenmüller, and others, have decided for the latter.[1] In addition to his royal dignity he sustained also the sacerdotal office: "he was priest of the Most High God;" and in this capacity he pronounced a benediction on Abraham. In return for his kindness, and especially from reverence to his priestly office, the patriarch gave him a tithe of all the spoil he had taken in that expedition, from which he was then returning.

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[1] Patrick, *in loc.* Josephus, *Antiq.* i. 9.

This is the sum of what Moses records respecting Melchisedec; and the only addition that can be made to the recital from the other passages above referred to is, that his priesthood was not derived from hereditary descent, but had been conferred on him by the immediate appointment of God.[2] Meagre, however, as this account is, there is something in the character and position of the individual to whom it refers of so singular a nature, as at once to excite curiosity, and stimulate further investigation. That in a land inhabited by the accursed race of Canaan, and at a time when the knowledge of the true God was confined apparently to Abraham and his dependents,[3] an individual descended from that race should have been found uniting in himself the two offices of priest and king, worshipping the true God of heaven and of earth,[4] and so eminent in dignity and piety that his blessing was gratefully received by Abraham, and the divinity of his priesthood acknowledged on the part of the patriarch by an offering to him of tithes, are circumstances which cannot fail to excite the surprise of every reader of the sacred narrative. It is natural for him to ask—Who or what was this extraordinary character? From what race did he spring? Whence did he derive his knowledge of the true God? Or how came he to be "a king of righteousness," and "a king of peace," as well as a priest of God, in the land of Canaan? To these questions the narrative of Moses furnishes no reply; and what is said of him in other parts of Scripture[5] only tends to heighten our curiosity, by the elevated rank which is there assigned to him as a type of the Messiah. Our only resource in such a case is probable conjecture, and to this it is not surprising that expositors of the Scriptures, both in ancient and modern times, should have had recourse; nor is it to be wondered at that the opinions which they have advocated on the subject have been both numerous and discordant. To recapitulate the whole of these would only be to occupy space which might be far more usefully filled; we shall therefore confine ourselves to a statement of one or two of the most prominent, with a brief view of the arguments by which they have been enforced.

1. By the Jewish expositors generally Melchisedec is said to have been Shem, the son of Noah, and this, as we learn from Epiphanius (*Hæres.* lv., p. 205), was also the opinion entertained by the Samaritans. It has likewise been held by a few Christian interpreters, amongst whom is Luther. The passages from Jewish writers advocating it have been carefully collected by Bochart (*Phaleg.*, lib. ii., c. 1), who has also very satisfactorily shown its absurdity. Apart from the decisive evidence furnished against it by the statement of Paul, that Melchisedec was one whose descent could not be identified with that of the Levites (*μὴ γενεαλογούμενος ἐξ ἀυτων*, Heb. vii. 5),—a statement which is not true of Shem, who was in the regular line of Levi's progenitors,—it seems highly unreasonable that Moses, who often mentions Shem, should here introduce him under another name, without giving any explanation as to the person really intended; nor is it easily conceivable that Abraham should have been described as "sojourning in a *strange* country," if he had been in the immediate vicinity of his ancestor Shem. The Jews, moreover, are not unanimous in this opinion, for Josephus tells us that Melchisedec was a prince of the Canaanites;[6] and in one place of the rabbinical book Sohar[7] he is spoken of as a *type of the King of true peace.*

2. Augustin and Theodoret severally inform us of a class of heretics in the early church, who received the name of Melchisedechians, from their holding the opinion that Melchisedec was a mighty divine power (*dei virtutem, μεγάλην τινα καὶ θείαν δυνάμιν*), superior to Christ, and the model after which Christ was formed. The founder of this sect was one Theodotus, an usurer, who seems to have flourished about the year 174.[8] An advance upon this opinion was made by Hierax, who, as we learn from Epiphanius, identified this divine power with the Holy Spirit (*Hær.* lv., p. 304). The sect seems to have commanded little attention, and their opinion is worthy of notice only as forming one of the heresies of the early church.

3. By some of the fathers, and not a few of the more modern expositors, Melchisedec has been regarded as the *Logos* or second person of the Trinity, who appeared to Abraham, not incarnate, but only, as Epiphanius expresses it, *ἐν ἰδέᾳ ἀνθρώπου*, in the model of man. In defence of this opinion, its advocates adduce, *first*, the acknowledged fact that such appearances were vouchsafed to the patriarchs, as in the case of Abraham, when "the *Lord*" communed with him respecting the destruction of Sodom, and of Jacob, when he wrestled with the angel, and saw "*God* face to face;" *secondly*, the evident mystery attached in Scripture to the person and character of Melchisedec, "of whom," says Paul, "we have many things to say and hard to be uttered;"[9] *thirdly*, the assertion of the same apostle, that Melchisedec was not mortal, implied in his declaration, that whilst other men who receive tithes die, "it is witnessed of him that he liveth;"[10] *fourthly*, the strong and unqualified terms in which the unearthly origin of the "order" of his priesthood, and its perpetual duration, are spoken of by the same apostle, as well as by the psalmist;"[11] *fifthly*, the language of Paul in regard to the mysterious existence of Melchisedec, as "without father, without mother, without descent, having neither beginning of days nor end of life,"—language strikingly applicable to Christ,—"whose goings forth have been of old from everlasting," but hardly to be understood of a mere man; and, *finally*, the circumstance of Melchisedec's receiving tithes as a free-will offering from Abraham, a homage which was rendered by the pious to none but the Almighty. On the side of this theory are ranked some eminent names both in the early and in the modern church. It is enough to mention those of Ambrose, Damianus, Moulin, Cunæus, Outrein, Hottinger, Starke, Gaillard, Ridgley, Hunter, Henry, and Brown. An able defence of this opinion has appeared in a work entitled *Melchizedek*, by the author of *Balaam*, *Elijah*, &c., London, 1834, the production, we believe, of a lady. The opinion is very fully examined and refuted in vol. ii. of Wardlaw's *Systematic Theology*, p. 315.

4. By far the most common opinion is, that Melchisedec was a righteous and powerful king, a worshipper and priest of the Most High God, in the land of Canaan, and a type of Jesus Christ. In support of this opinion it is contended, *first*, that the mysterious character attributed to Melchisedec in Scripture is nothing more than belongs to all the prophetical types; and that when Paul says he has many things to say respecting him which are hard to be uttered,

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[1] See besides Rosenmüller's Scholia on the passage, the commentaries of Tuch and Knobel.
[2] Heb. vii. 3. Fuller *on Gen.* xiv. 18.
[3] Josh. xxiv. 2.
[4] Gen. xiv. 19.
[5] Ps. cx. 4. Heb. vi. 20.
[6] Χαναναίων δυνάστης. *De bell. Jud.* vii. 18.
[7] Lech lecha, fol. 60, col. 237, ed. Sulz., quoted in Professor Tholuck's *Comment. zum briefe an d. Heb.* in loc.
[8] Theodoret. *Hær. fab.*, lib. ii., cap. 6. ap. Suicer. *Thes. Eccl.*
[9] Heb. v. 11.
[10] Heb. vii. 8.
[11] Heb. vii. 3, &c. Ps. cx. 4.

he only means, that owing to the carnality of those to whom he was writing, the revelation which he was about to give of the *spiritual* character of Melchisedec as a type of Christ, would not be easily apprehended;[1] *secondly*, that his being described as ἀπατωρ και ἀμήτωρ, may mean that he was the first of his family who sustained the royal and sacerdotal dignity; or, if it be understood naturally, it implies nothing more than that his descent was not matter of record, in the same way as Sarah is called ἀμήτωρ by Philo, because her mother's name is not known, or as Servius Tullius is said by Livy to have been born *patre nullo, matre serva*, because only his mother's name (Cornicula) was matter of history; *thirdly*, that what is said of his being "without beginning of days or end of life," refers merely to our ignorance of the time and manner of his birth and of his death, which are purposely left unrecorded, in order that he might serve as a type of Christ, "who ever liveth;" *fourthly*, that the expression, "of whom it is testified that he liveth," is only a concise repetition of the preceding statement;[2] *fifthly*, that in all the *certain* instances of Divine appearances recorded in the Old Testament, the fact of the Deity's being present is made apparent in the narrative itself; and that this not being done in the case of Melchisedec renders it unjustifiable, without express authority from some other part of Scripture, to suppose that he was such an appearance; *sixthly*, that had Melchisedec been himself the Son of God, the apostle would not have said that he was "made like (ἀφωμοιωμένος, *assimilatus, likened to, compared to*) the Son of God," for this would have been to compare him with himself; *seventhly*, that no sufficient reason is apparent from the narrative for so extraordinary a revelation as that of the second person of the Trinity in human shape, nor does any end worthy of such means seem to have been answered by the interview; and, *finally*, that Abraham's offering of a tithe of the spoil might with great propriety be presented to Melchisedec, though only a man, as an act of homage, not to himself, but to that God whose priest he was, and in whose name he had blessed the patriarch. This view of the subject has been adopted by a majority of the fathers, as well as of modern divines. It has been strenuously defended by Dr Owen, in his work on the Hebrews, where he denounces the opposite opinion as a series of "groundless fables" and "woful mistakes;" and has received the suffrages of the greater part of those who have commented upon that epistle, amongst whom may be mentioned the names of Calvin, Cameron, Scott, Blomfield, Stuart, Kuinoel, Tholuck, and Ebrard. It may be regarded as the *common* opinion of the orthodox church.

According to this opinion, the reasoning of St Paul, in the passage referred to, goes to establish an analogy between Melchisedec and Christ, in respect of the following points:—*First*, of *name* and *designation*, both being denominated "king of righteousness," and "king of peace;" *secondly*, of *obscurity of descent*, both being without beginning of days or end of life,—the one because his genealogy is not recorded, the other, because with regard to him this was literally true; *thirdly*, of *the homage rendered to both by their receiving tithes as a free-will offering*, the one in the name of the God whom he served, the other in his own name; *fourthly*, of *the peculiar character of the office they sustained*, neither having had either predecessors or successors, the one because God arranged it so, the other because it was of necessity so; and, *fifthly*, of *the superiority of both to the priests under the law*, the one having blessed, as a superior, Abraham, the father of Levi, the other having abolished the whole economy of the Levitical priesthood by the sacrifice of himself.[3]

(W. L. A.)

MELCHTHAL, Arnold of, one of the restorers of Swiss freedom, was the son of a wealthy proprietor, and was born in the canton of Unterwalden, in the latter half of the thirteenth century. His real name was Winckelried, but he was universally known by the name of his residence. At this time Switzerland groaned beneath the oppression of Albert of Austria. One day the valet of Handenberg, an Austrian bailiff, seized upon a yoke of oxen belonging to Melchthal's father, and, as he was driving them away, remarked, that peasants, if they wanted to eat bread, should hold the plough themselves. Stung by such insolent rapacity, young Melchthal struck the menial to the ground, and fled from punishment to his native fastnesses. The information that his father's eyes had been put out by the revengeful tyrant, served only to strengthen his determination to free his country. He received into his confidence Fürst, of the canton of Uri, and Stauffacher, of the canton of Schwytz. On a night of November 1307 the three patriots met on the solitary banks of the Lake of Lucerne, and there they took an oath to advocate in their several cantons the cause of freedom, and to drown every revengeful feeling and every personal motive in the one prevailing desire for the liberty of their country. The bold feats of William Tell, in the same month, accelerated the execution of their plans, and raised to arms the natives of Uri, Schwytz, and Unterwalden. Arnold of Melchthal, along with his compatriots Fürst and Stauffacher, led the mountaineers on to victory. On the battlefield of Sempach he is said to have attempted, single-handed, to break an impregnable line of Austrian lances, and to have fallen with "a sheaf of spears" sticking in his breast.

MELDRUM, Old, a burgh of barony and a parish of Scotland, Aberdeenshire, 18 miles N.N.W. of Aberdeen. The town contains an Established, a Free, a United Presbyterian, and an Episcopal church; two schools, and a savings-bank. The inhabitants are employed in agriculture, weaving, brewing, distilling, &c. Market-day, Saturday. Pop. (1851) of burgh, 1579.

MELEAGER, a Greek epigrammatist, and the collector of the first Anthologia that is known, was the son of Eucrates, and flourished at Gadara in Palestine about 60 B.C. His collection was made from the works of forty-six authors, and was entitled Στέφανος, *The Garland*. The authors were Anytus, Myro, Sappho, Melanippides, Simonides, Nossis, Rhianus, Erinna, Alcæus, Samillo, Leonidas, Mnasalces, Pamphilus, Pancrates, Tymnes, Nicias, Euphemus, Damagetus, Callimachus, Euphorion, Hegisippus, Perseus, Diotimus, Menecrates, Nicænetes, Phaennus, Simmias, Parthenis, Bacchylides, Anacreon, Anthemius, Archilochus, Alexander Œtolus, Polycletus, Polystratus, Antipater, Posidippus, Hedyles, Sicelides, Plato, Aratus, Cheremon, Phedimus, Antagoras, Theodorides, and Phanias. This collection has disappeared, but we possess 131 epigrams, which are said to have been the production of this poet. They are written principally on amorous subjects, and are remarkable for the elegance of their versification. The best editions of Meleager are that of Manso (Jena 1789), of Meinecke (Lips. 1789), and at Græfe (Lips 1811). See Fabricius, *Biblioth. Græca*, tom. iv.; *Prolegomena* to the

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[1] The word he uses is δυσερμήνευτος, which the Vulgate renders *ininterpretabilis*.

[2] Wardlaw rejects this with the remark, "This will not do," and adopts in preference the interpretation which refers "he liveth" to Christ; an interpretation, again, which Ebrard says "is mere nonsense." We beg to dissent from both decisions. That the interpretation which Wardlaw rejects "*will* do" Ebrard shows; and that the view which Ebrard denounces is not "nonsense" is sufficiently proved by Wardlaw.

[3] See Chrysostom, *Homil.*; Calvin, *Comment.*; Tholuck, *Comment.* in loco.; Alexander's *Congregational Lecture*, 2d edit., p. 423; &c.

Anthologia Græca of Jacobs; Reiske in his Preface to his *Anthologia Græca;* Schneider in his *Analecta Critica,* fascic. 1; Burette, *Mémoires de l'Acad. des Inscript.* xix.

MELEDA (anciently *Melita*), an island of the Adriatic, off the coast of Dalmatia, from which it is about 3 miles distant, and 17 W.N.W. of Ragusa. Length 23 miles; breadth 4 miles. The island contains lofty mountains of a bare and dry aspect; and there are also some fertile but not well cultivated valleys, producing corn, wine, vegetables, and fruits. Sheep, goats, bees, and silk-worms are reared in large numbers and with considerable care. The coast is irregular, and contains numerous harbours, one of which, Palazzo, on the N. of the island, is reckoned the best in Dalmatia. Meleda has been supposed by some to be the scene of the shipwreck of St Paul; but this opinion is now very generally abandoned in favour of the modern Malta. Pop. 900.

MELENDEZ VALDES, Juan, a distinguished poet of Spain, was born at La Ribera del Fresno in Estremadura, on the 11th of March 1754. After studying philosophy at Madrid he went to the university of Salamanca at the age of eighteen, where he pursued the study of law, and made the acquaintance of some of the most eminent literary men of the time in Spain. His earlier efforts at versification were in imitation of Lobo, who had still many admirers, but who belonged to a bad school. The elder Moratin, however, who was thoroughly opposed to the vicious poetical taste of his time, was beginning to leave traces of his influence on the mind of the young follower of Lobo, when a fortunate accident brought Cadahalso to Salamanca. The sympathetic discernment of this eminent poet and soldier soon detected the latent genius of Melendez, and induced him to take him to his house, where he spent great pains in disclosing to the young poet the beauties of the elder literature of Spain, and of the cultivated nations of Europe. It was through Cadahalso that Melendez first became acquainted with the literature of England, which subsequently exerted so marked an influence on his poetic development. He was accustomed to remark in later days, that it was John Locke who first taught him to reason, and that four lines of Pope's *Essay on Man* were superior to all that poet ever wrote. The devoted friendship of Cadahalso met, accordingly, with an ample reward in the great success of his pupil; and it was afterwards said, with as much truthfulness as point, that "among all the works of Cadahalso, the best was Melendez." But the most commanding mind of the time was that of Jovellanos, whose friendship Melendez afterwards formed through Gonzales. This new relationship at once exercised a decided and salutary influence over him. In 1780 he obtained the prize of the Spanish Academy for the best eclogue, although he had to contend with a formidable rival in Yriarte, his senior in years, and in court favour. The performance of the latter was written in the declamatory style of some of the older and weaker Spanish pastorals; while the *Batilo* of the former was fresh from the fields, and, as one of the adjudicators said, "seemed absolutely to smell of their wild flowers." Melendez, on going to Madrid the following year, was received with much cordiality by Jovellanos, and received new honours from the academy of San Fernando for a Pindaric Ode *On the Glory of the Arts.* He was shortly after appointed professor of the humanities or philology at Salamanca, which enabled him to return to his favourite haunts on the banks of the Tórmes. In 1784 he was induced by Jovellanos to compete for the prize offered by the city of Madrid for a dramatic performance. His comedy of *The Wedding of Camacho* (*Las Bodas de Camacho*) secured the vote of the judges, but was received coldly by the public, and soon fell into neglect. The talent of Melendez was not dramatic; and he made an attempt the following year to retrieve his fallen fortunes by presenting the public with a volume of lyrics and pastorals; a species of composition for which his genius was peculiarly adapted. His success was extraordinary. The genuine simplicity and tenderness of those pieces, their elegant versification and light gracefulness, their rich, truthful descriptions of natural scenery,—all combined to communicate to them a fascination such as had not been known in Spain since the disappearance of the eminent names of the sixteenth and seventeenth centuries. Indeed, so subtle and exquisite is the grace of those charming poems, that it is precisely the sort of beauty which is sure to be lost in being strained through any translation. Three counterfeit editions of this small volume appeared in 1785, and were sold off as fast as they were printed.

In an unfortunate hour Melendez, the darling of the court, resolved to leave his happy retirement, and solicit a place under the government. In 1789 he was made a judge; and in 1791 was elevated to a position of honour in the chancery of Valladolid: this new duty did not, however, estrange him from the muse. He published in 1797 a new and greatly enlarged edition of his works, which he dedicated to the Prince of the Peace, with whose misgovernment the poet was now too closely connected, from the necessities of his political position. This new effort did not add greatly to his fame. The influence of English and German literature was more obvious than salutary. In his *Ode to Winter* he imitates Thomson, and *The Fall of Lucifer* is a faint echo of Milton. The fervid glow of the rare old Castilian verse was not consistent with the laboured moralizings and dreary metaphysical discussions which Melendez, after the manner of Jovellanos, now packed into his lines. The prince was flattered by the dedication, however, and attached the poet to the court at Madrid, where Jovellanos was a minister of state. But the next year saw these eminent men in exile; and it was not till 1802 that Melendez, by the mitigation of his persecution, was permitted to return to the scene of his early fame at Salamanca. After six years came the revolution of Aranjuez, when he hastened to Madrid only to be in time to witness the ascendancy of the French power, to which he, in a moment of infatuation, gave in his adherence. On being sent as a commissioner to Oviedo, he was led out by the infuriated populace to be shot; and on another occasion his house was sacked, and his valuable library destroyed, by the very party whose interests he served. Melendez fled; and after dragging out four miserable years in exile in the south of France, he died at Montpellier on the 24th of May 1817.

Melendez solaced himself during the heavy hours of exile by preparing a complete edition of his works, with numerous corrections and additions, which was published, with a Life of the author, by Quintana, at Madrid, in 4 vols. 8vo. His anacreontics still retain their fame; and he is universally regarded as the greatest poet Spain had known for an entire century. (See Ticknor's *History of Spanish Literature,* vol. iii.)

MELETIUS, Bishop of Antioch, a famous ecclesiastic, was born about the beginning of the fourth century at Melitene (*Malatiah*) in Armenia Minor. His first important pastorate, the bishopric of Sebaste, was rendered so intolerable, through the stubborn conduct of the people, that he resigned it shortly after his appointment, and retired to Berœa (*Aleppo*) in Syria. At this time the Arian controversy was engrossing the minds of the Christians of the East, and was fast extinguishing all deep and true piety. The pastors fed their flocks with nothing but the dry formulæ of doctrine and the vehement ebullitions of sectarian zeal. But Meletius, keeping ever in view the design of the priesthood, endeavoured, both by his ministrations in the pulpit and by his walk in private life, to recommend to his people the essential doctrines of the gospel. He thus undesignedly secured the respect of both the factions in the church, and was elevated by universal consent to the

Meletius.

see of Antioch in 360. The public conduct of Meletius now became more decided. He saw that in his influential position he was bound to act a part in a dispute that was interrupting the concord of the Christian world. Accordingly, in his inaugural discourse in 361, he expressed, in subdued yet unmistakeable terms, his sympathy with the orthodox party. This confession awakened the slumbering spirit of controversy in the church of Antioch. The Arians forthwith charged Meletius with Sabellianism and other crimes, and in the course of a month he was banished to his native Melitene by command of the Emperor Constantius. At the same time the orthodox party in the church of Antioch seceded from the communion of the Arians. On the accession of the Emperor Julian in 362 Meletius was recalled from exile. He now bent all his energies to effect a union between the Eustathians and the orthodox section that had separated from the Arians at his own deposition; but the former party, although they had seceded from the church of Antioch on the same grounds as the latter, could not sympathize with the liberal-minded Meletius, and declared that they would recognise no bishop who had been consecrated by Arians. The Council of Alexandria interfered to settle this dissension, and sent Lucifer of Cagliari to Antioch. But that hot-headed bishop was the worst mediator that could have been found; and he immediately destroyed all hope of a reconciliation, by ordaining Paulinus bishop of the Eustathians. Soon after the accession of Valens in 364 Meletius was again banished. He was recalled, along with other exiles, by an edict of Gratian in 378; and not long afterwards he was reinstated in his bishopric. His exertions were again turned towards a union with the Eustathians, but were frustrated by the unrelenting prejudice of their bishop, Paulinus. Meletius died at an advanced age while attending the Council of Constantinople in 381. His body was conveyed to Antioch, and buried with great honour beside the tomb of the martyr Babylas. Gregory of Nyssa pronounced his funeral oration. A part of the inaugural sermon of Meletius at Antioch is printed in the 5th vol. of Galland's *Bibliotheca Patrum*.

Meletius, the founder of the sect of the Meletians, was Bishop of Lycopolis in Thebais in the beginning of the fourth century. During the bitter persecutions that assailed the Christians in the reigns of Diocletian and Maximian, he and his superior, Peter, Archbishop of Alexandria, were fellow-prisoners for the faith. Torture and hardship meanwhile were wringing from many an abjuration of their religion. Some of these backsliders, however, could not enjoy in peace the freedom they had so ignominiously bought, and, repairing to the two imprisoned bishops, they desired to be reconciled to the church. Peter at once declared that their request ought to be granted after they had undergone a suitable penance; but Meletius, occupying as a metropolitan a rank second only to the archbishop, ventured to oppose this decision, and refused to have any intercourse with traitors to the faith until the close of the persecution. The question was then submitted to the vote of the imprisoned Christians, and was settled by a majority agreeing with the opinion of Meletius. The schism, thus begun in a dungeon, was carried by the prisoners to the mines of Phœnon in Arabia Petræa, and rose into prominence when Meletius was finally liberated. The headstrong bishop then set himself to overturn the authority of Peter in his archbishopric of Alexandria. He travelled through the patriarchate, ordaining and excommunicating in the most arbitrary manner, attracting to himself many followers, and utterly disregarding all the protestations of the Egyptian bishops, and the sentence of deposition that Peter launched against him. This proselytizing tour was afterwards extended into Palestine. At length, in 325, the Council of Nice arrested Meletius in his reckless career, and fixed him down at Lycopolis as a mere titular bishop, without any active jurisdiction. He did not long survive this sentence.

The Meletians, or, as they called themselves, "The Church of the Martyrs," were chiefly characterized by opposition to the Patriarch of Alexandria. So prominent was this feature that they afterwards sacrificed their orthodoxy, and entered into alliance with the Arians against Athanasius. They continued a distinct sect, however, till the fifth century.

Melfi || Meli.

MELFI, a town of Naples, province of Basilicata, on a high volcanic eminence, 75 miles E.N.E. of Naples, and 34 S. of Foggia. The town has narrow streets; and is defended by walls, now in a ruinous condition, and by an ancient Norman castle. On the 14th August 1851, Melfi was visited by a tremendous earthquake; the ancient cathedral with its tower was laid in ruins, the college and several churches and monasteries were destroyed, 163 houses were thrown down and 278 injured, and more than 600 of the inhabitants perished in the ruins. This town was formerly the capital of the Norman possessions in Southern Italy, and the seat of the baronial councils. The hall where these councils used to meet has been in recent times changed into a theatre. The neighbouring country is rich in wine, which forms the principal article of trade. Pop. 9582.

MELI, Giovanni, born the 4th of May 1740, died the 20th of December 1815, at Palermo in Sicily. Although his works are all written in the vernacular of his native island, he has left a reputation as one of the greatest modern poets of Italy. He early became a graduate in the faculty of medicine, and at the same time displayed a strong sympathy for the philosophical doctrines of Wolfius. His poetical talents, however, made him accepted in literary rather than scientific circles. His Italian verses were admired for their smoothness, and for their delicate sentiments and graceful descriptions. He was induced soon after by the Prince of Campofranco to write his verses in the Sicilian dialect; and while it was with considerable reluctance that he complied with the wishes of the prince, his patron, he nevertheless applied himself to his new vocation with so much energy and taste, that he ultimately gained for himself a place among the brightest names in Italian literature. He took the language of the people, adopted all the grace and strength with which a southern and imaginative race love to clothe their affections and feelings, and applied it to so many different styles, forms, and subjects, as to show its flexibility, aptitude, and inexhaustible power in expressing all forms of sentiment, from the tenderest to the strongest, from the most familiar to the most abstract, without losing its vivacity, harmony, and dignity. Not that he was the first poet who cultivated his native dialect: not a few poets of some note, and above all Vitali, called "*Il Cieco di Ganci*" (the blind poet of Ganci), who was the author of an epic entitled *Sicily Delivered, or the Conquest of Sicily by the Normans*, had preceded Meli; but none of them had enjoyed the advantage of a liberal education. Meli's first poem, *La Fata Galante*, in eight cantos, published before he was twenty, won for him at once a high reputation, which his subsequent works did not diminish. His longest poem, *Don Chisciotte* (Don Quixote), in 12 cantos, is of the mock-heroic type, resembling the famous novel of Cervantes. The *Origine del Mondo*, a satire on the philosophical doctrine of pantheism, is a more original production, and written much in the same style. He has attempted, with admirable success, all styles of poetry except the dramatic; but the species of composition in which he truly excels is in eclogues and anacreontics. The life-like spontaneity of his dialogues, and the direct simplicity of his odes, have seldom been surpassed even by the classic and copious literature of Italy. Meli has been compared to Burns; and his influence over the Italian mind would have been equal to that of the Scottish poet over the English, had Italy enjoyed the social and political advantages of England. Yet the fame of Meli, even during his lifetime, was not confined to the country in whose language he sang. Alfieri, Cesarotti, Rezzonico, Denina, Metastasio, Pananti, and Casti, the greatest men of the day, admired his genius, although they regretted he had not written in the language of Italy. No less a man than Foscolo attempted to translate his poetry into Italian. Professor Rosini of Pisa accomplished this task, although with indifferent success. The translations into the other dialects of Italy have been more happy. Gregorovius, the author of *Wanderings in Corsica*, is at present (1857) translating them into German.

Meli, having studied medicine, was appointed to the chair of chemistry at the university of Palermo, a position which he held till his death. An edition of his essays on scientific subjects was published in Sicily, of which the most esteemed are his *Riflessioni sul Meccanismo della Natura Rapporto alla Conservazione e Riparazione degl' Individui*, Palermo, 1839. A medal was struck in honour of him by order of the Prince of Syracuse, bearing his portrait, with the inscription, "*Anacreonti Siculo*." A tomb was erected in St Francesco, Palermo, by his family; and the inhabitants of Palermo raised a public monument to him in one of the squares of their town. (See *Poesie di Giovanni Meli*, Palermo, 1847; and No. IX. of the *Foreign Quarterly Review*, 1829. (E. F.)

MELISSUS, a philosopher of the Eleatic school, was born in Samos, and flourished about 444 B.C. He took a very active part in the political struggles of his country, and his fellow-citizens honoured him on one occasion with the command of a naval armament. Little more is known respecting his life. Like almost all the philosophers of this epoch of Greek speculation, he composed a treatise on "Being and Nature" (περι φυσέως). He raised a vigorous protest against the empirical sensualism of the Ionic philosophers, among whom he spent his life in his native island. His master, Parmenides, maintained that the senses could furnish nothing certain, and that the study of being, essentially and absolutely one and immoveable, was the only occupation worthy of a philosopher. Zeno, again, had proved to the Ionians that to admit matter is to admit divisibility, which is the condition of extension; but being is indivisible, and hence matter has only a phenomenal existence. Such was the position of antagonism of the two schools when Melissus appeared. He attempted to enlarge the basis of the Eleatic school by borrowing the notions of time and space admitted by the Ionians, but ignored by Parmenides. Having pronounced being to be infinite and one, Melissus applied the same quality to time and space, which led him to their identification. Nothing relative, according to him, can be eternal; motion is impossible, for being is infinite, and motion requires a void. Aristotle (*Met.* i. 8) accuses Melissus of confounding being with matter, but places him higher than Parmenides as a philosopher. As for the existence of the gods, Melissus, like the rest of his school after the time of Xenophanes, declared that it was impossible to arrive at any certainty. Melissus was the last representative of the Eleatic doctrines. (See the Fragments of Melissus, collected by Brandis, *Comment. Eleat.*, Copenhagen, 1813.)

MELKSHAM, a market-town of England, Wiltshire, situated on a slope near the Avon, 26 miles N.W. of Salisbury, and 96 W. by S. from London. It consists of one long and irregular street; and the houses are of stone, and well built. On the other side of the Avon, which is here crossed by a handsome stone bridge, stands a suburb, known by the name of The City. The church, which is believed to be as old as the twelfth century, is in the form of a cross, with a tower, which stood formerly in the centre, but was removed in 1845 to the west end. Melksham has also places of worship for Independents, Baptists, Methodists, and Quakers. There is a large market-house and town-hall, built in 1847, in the Grecian style of architecture. Melksham has, besides, national and British schools, and a savings-bank. In the neighbourhood mineral springs were discovered some time ago, near which have been erected baths and houses for the accommodation of visitors. In the reign of William the Conqueror Melksham seems to have been a place of considerable importance. It has since fallen off; but of late years has been raised by the introduction of the cloth manufacture. Besides this manufacture, and that of ropes, the town has large corn mills, and a considerable trade in leather and malt. It is also the seat of a county court; and petty sessions are held here. Pop. of town (1851) 2931.

MELLONI, MACEDONIO, a distinguished natural philosopher, born at Parma in the year 1800. Before he was of an age to explain or even to understand his own feelings, he delighted to pass whole nights in contemplation out of doors, wandering in the fields—a habit which gave a very great impulse to his scientific genius. With a decision, as resolute as it was prompt, he did not mistake his vocation, but at once applied himself to his favourite science, in which at an early age he made great progress. Little was known at that time among natural philosophers respecting the radiation of heat; and Melloni set early to work to advance the cause of discovery in that department of science. He had scarcely left school when the chair of natural philosophy was offered him at the university of Parma; and hygrometry being the special branch allotted to him, he taught it from 1824 to 1831. In the progress of his researches into the nature of radiation he found occasion to employ an ingenious instrument termed the *thermoscopium*, invented by Nobili, a distinguished physicist of that time, for determining slight variations in the temperature of bodies. Nobili himself appreciated the importance of the results obtained by his young friend, and gave an account of them in an article in the *Bibliothèque de Genève*. In 1831 political events in Romagna and the duchies compelled Melloni to expatriate himself. He found an asylum in France, where he arrived with his thermoscopium. He there became the friend of Arago, the celebrated secretary of the Académie des Sciences, and was subsequently appointed to a professorship in the college of Dôle, in the department of Jura, a situation which his thirst for discovery induced him to resign. He then went to Geneva, where he was welcomed by Pier Prevost and Auguste de la Rive, who placed at his disposal their rich collection of scientific instruments. After six months' assiduous experimenting he succeeded in establishing a number of important facts with regard to the radiation of heat both through solids and liquids. He hastened to Paris to lay his discoveries before the Academy of Sciences, but being received coldly by that body, Melloni resolved to publish the results of his experiments; this led to his being awarded the Rumford medal by the Royal Society of London. After receiving this foreign tribute to his genius, the Institute of France, in the person of Biot, also acknowledged his merits. (See *Mémoirs de l'Académie des Sciences de Paris*, vol. xiv.) The paper submitted to the academy by Melloni is entitled, *Descrizione ed Usi di un Apparecchio proprio a Manifestare ed a Misurare i Fenomeni del Calorico Raggiante.* Melloni had now secured his place among the most eminent men of Europe; and, through the influence of Arago and Humboldt, he was enabled to return to his native country with the consent of Austria, then the ruling power in Italy. Under these circumstances, the King of Naples, at the suggestion of Arago, did not hesitate to appoint Melloni director of the meteorological observatory, then in course of erection on the slope of Vesuvius. Among the many brilliant results obtained by Melloni in this new sphere, must be mentioned his discovery of heat in the lunar light, which led to the solution of one of the most important problems of modern physical science, viz., the analogy of radiant heat to light. At the meeting of the Italian scientific congress at Naples in 1845, Melloni was elected vice-president of the physical section. He was made a member of the commission to establish lighthouses on the coast of the kingdom, when he published a very able popular account of Fresnel's *pharos*. The political events of 1848, and the reaction which followed, again interrupted Melloni's scientific pursuits; for although he had taken no part in politics during his residence at Naples, he was in 1849 ejected from his post simply for the liberal opinions he had once professed, and which he still held. He retired to his villa at Portici, near Naples, where, amid bitterness of spirit and disappointment, his love of science never abated. In 1850 he published there the first volume of *La Termocrosi, o la Colorazione Calorifica*, which he dedicated to Francis Arago and Alexander Humboldt. This compilation, in which he describes his own conclusions, and sketches methodically the progress of science since his first discovery, did not distract his mind from experimental researches. The last years of his life were devoted to the study of electricity, and he communicated many new facts in this branch of science to the *Bibliothèque Universelle de Genève*. Melloni opposed with great discrimination several ideas of Faraday with regard to the diminution of velocity observed in an electric current passing through submarine or subterranean wires, as compared with an equal current passing through wires suspended in the air. The Englishman had made experiments, from which he endeavoured to deduce a confirmation of his theory of conductability, to the conclusiveness of which, however, the Italian demurred.

He died of cholera at his villa of Portici on the 11th of August 1854. Besides his principal work, *La Termocrosi*, which he left incomplete, or at least unpublished, he contributed numerous papers to the *Annales de Chimie et Physique*, the *Comptes Rendus* of the French Academy; the *Bibliothèque de Genève*; the *Atti della Reale Academia di Napoli*; and the *Museo di Scienze e Letteratura*, a Neapolitan periodical, in which may be found his discussions and observations on the action of calamite and the electric current, on polarized light, on ponderable bodies, and also his objections to the theory of Faraday. (For further information respecting Melloni's discoveries, see the *Sixth Dissertation*, chap. vi., sect. 8; also the article HEAT.) (E. F.)

MELMOTH, WILLIAM, a learned member of Lincoln's Inn, was born in the year 1666. He was called to the bar in 1719, was treasurer of Lincoln's Inn for the year 1730, and died in 1743. In conjunction with Mr Peere Williams, Mr Melmoth was the publisher of Vernon's *Reports*, under an order of the Court of Chancery. But the performance for which he is justly held in remembrance is *The Great Importance of a Religious Life Considered*, London 1749; of which above 100,000 copies were sold during the last century. This admirable treatise was published anonymously, and was for some time erroneously attributed to John Percival, the first Earl of Egmont. A new edition of this work, with a memoir of the author and four appendices, was privately printed as a present to the benchers of Lincoln's Inn by Charles P. Cooper, Esq., London, 1849. (See *Memoirs of William Melmoth*, published by his son, 1796.)

MELMOTH, *William*, son of the preceding, was born in 1710. He was bred to the law, and appointed a commissioner of bankrupts in 1756; but the greater part of his life was spent in retirement, partly at Shrewsbury and partly at Bath, where he was distinguished alike for integrity of conduct and for scholarly culture and an elegant taste. He first appeared as a writer in 1742, when, under the name of Sir Thomas Fitzosborne, he published two volumes of *Letters on Several Subjects*, which have been much admired for the just and liberal remarks with which they abound on various topics, moral and literary. In 1747 he published a translation of the Letters of Pliny, in 2 vols. 8vo, which, for elegance, precision, and correctness, is one of the best versions of a Latin author that has appeared in our language. In 1753 he published a translation of Cicero's Letters, in 3 vols., which were followed up in 1773 and 1779 by richly annotated translations of the treatises *De Amicitia* and *De Senectute*. In his remarks on the treatise *De Amicitia* he combated the opinion of Lord Shaftesbury, who had imputed it to Christianity as a defect, that it contained no precepts in favour of friendship; and also that of Soame Jenyns, who had represented this very omission as a proof of its divine origin. The concluding work of Mr Melmoth consisted of memoirs of his father, published in 1796. He died at Bath on the 15th of March 1799, at the age of eighty-nine.

MELODICA, a keyed instrument in the form of a harpsichord, and having a flute register of three and a half octaves, from the lowest G of the violin upwards. It was invented by J. A. Stein at Augsburg in 1770.

MELODICON, a keyed instrument invented by Peter Riffelsen at Copenhagen in 1803. Its sounds were produced by the friction of pointed rods upon a revolving cylinder of steel. Riffelsen had previously constructed another instrument with tuning-forks of different dimensions.

MELODION, an instrument invented by Dietz at Emmerich in the Netherlands. It was in the form of a small harpsichord, with a pedal which moved a wheel. The sounds were produced by metal rods caused to vibrate by the friction of the wheel.

MELODY. See MUSIC.

MELPOMENE, in fabulous history, one of the muses, daughter of Jupiter and Mnemosyne, who presided over tragedy. Horace has addressed the finest of his odes to her, as to the patroness of lyric poetry. She was generally represented as a young woman with a serious countenance; her garments were splendid; she wore a buskin and a garland of vine leaves, and held a dagger, or the club of Heracles, in one hand, with a sceptre and crown in the other.

MELROSE, a burgh of barony of Scotland, Roxburghshire, on the Tweed, near the N. foot of the Eildon Hills, 36 miles S. of Edinburgh, and 12 N.W. of Jedburgh. The town probably derives its name from *Moel* or *Mull-rhos*, a point or headland in the river; and the site was occupied by a Culdee house founded in 635. This was superseded by the Cistercian abbey, begun by David I. in 1136, and completed in 1146. This building having been destroyed by the English under Edward II. in 1322, was rebuilt by Bruce four years afterwards; and the heart of that monarch, after having been carried to Spain by Douglas, was, on the death of that earl brought home and buried beneath the high altar. The abbey was completed by James IV.; but was again destroyed by the English in 1545. Although this fine building suffered considerably from the hands of the Reformers, the main cause of its present ruinous condition must be traced to the hostile incursions of the English, and to the carelessness and depredations of later times, when the stones were frequently carried off and employed in building other edifices. The church was laid out in the form of a cross, of which the length of the nave and choir was 258 feet, and the breadth 79; the length of the transept 130 feet, and the breadth 44. The building was surmounted by a tower, part of which is still standing along with the walls of the nave, choir, and transept. The rest of the abbey, however, has been destroyed, except a portion of the walls of the cloisters. Its architecture is not reducible to any of Rickman's styles of English Gothic. It more nearly approaches to continental structures, especially Strasburg cathedral; and the whole building is profusely ornamented with rich and exquisite carved work. Some of the piers are crowned with foliage, so delicately chiselled, that a straw may be thrust in between the various stalks and leaves. The window and door in the south transept are considered the most perfect parts of the building, and are very richly decorated. The eastern window is also much admired for the symmetry of its form and the richness and delicacy of its ornaments. Its dimensions are 36 feet in height by 16 in breadth. The grave of Alexander II. is pointed out here, as lying under a marble slab not far from the high altar; and many others, noblemen and priests, are buried in the abbey, including several of the Douglas family. A beautiful description of Melrose is given by Sir Walter Scott in the *Lay of the Last Minstrel.* Pop. (1851) of town, 966.

MELSUNGEN, a town of Hesse-Cassel, situated on the left bank of the Fulda, 13 miles S. of Cassel. The town is walled, with four gates; and contains a castle, church, and hospital. The manufactures consist of woollen cloth, leather, tiles, &c.; and there is a considerable trade in wood and linen. Pop. 4220.

MELTON-MOWBRAY, a market-town of England, in Leicestershire, situated at the confluence of the Wreak and Eye, 14 miles N.E. of Leicester, and 92 N. by W. of London. The town is well and substantially built, chiefly of brick; and consists of two main streets. The parish church is a large and handsome Gothic building, in the form of a cross, with a lofty and richly adorned tower in the centre. There are also churches for Independents, Wesleyan and Primitive Methodists, and Roman Catholics; several schools and alms-houses; besides a subscription library, news-room, and theatre. Melton owes its prosperity and celebrity to its being the centre of the hunting district, and the seat of the Melton Hunt. It is on this account resorted to by the leading sporting men of England, and by some from other countries, during the season, which lasts from November till March. Upwards of 800 horses, with their grooms, &c., may be accommodated in the excellent stables of Melton; and in the neighbourhood there are many hunting seats. The chief manufactures of the place are lace and hosiery; and the trade consists chiefly in pork pies and Stilton cheese, which is made here, though it takes its name from Stilton in Huntingdonshire, where it was first sold. John Henley the orator was born here in 1692; and Melton is also remarkable as the scene of a defeat of the parliamentary troops by the royalists in 1644. Pop. (1851) 4391.

MELUN, a town of France, capital of the department of Seine-et-Marne, is pleasantly situated on the Seine, 27 miles S.S.E. of Paris. The town stands on both sides of the river, especially on a slope on the right bank, and partly on an island joined by two bridges to the other parts of the town. The oldest part of Melun is that on the island; and it is well, though irregularly built, containing a large prison, a ruined palace, and the church of Notre Dame. The part on the right bank, called St Aspais, includes a large and regularly built square, an old Gothic church, the ruins of an old abbey, the prefecture, formerly a Benedictine abbey, a theatre, baths, &c. On the left side of the river stand the cavalry barracks. The town has a public library, as well as a college and several schools. Melun has manufactures of woollen and linen cloth, leather, china, plaster, &c.; and there is a considerable trade in grain. This town was anciently called Melodunum, and was taken by the Romans under Labienus, one of Cæsar's generals. It was afterwards captured by the English under Henry V. in 1420, but was recovered by the French fifteen years afterwards. Pop. (1851) 7528.

MELVILLE, ANDREW, a Scottish divine of distinguished talents and learning, was born at Baldovy in Forfarshire on the 1st of August 1545. His father, Richard Melville, who was connected with a family which boasted its descent from the blood-royal, was slain at the disastrous battle of Pinkie, fought on the 10th of September 1547, when Andrew, the youngest of nine sons, had only completed his second year. He lost his mother during the same year, and the care of the orphan boy devolved upon his eldest brother Richard, who afterwards became minister of the adjacent parish of Marytoun. As he early discovered great aptitude for learning, he was removed to Montrose, where he was instructed in the rudiments of the Latin language. In the year 1559 he was sent to the university of St Andrews, where he became a student in St Mary's College, and greatly distinguished himself by his early proficiency in classical learning, particularly in his knowledge of Greek, a language at that time unknown even to the lecturer on Aristotle of his university. Melville left this university with the reputation of "the best philosopher, poet, and Grecian of any young master in the land;" and in the autumn of 1564, when he had completed his nineteenth year, he proceeded to Paris with the view of prosecuting his studies at the university of that city, then at the height of its celebrity. Here Melville enjoyed the advantage of hearing the prelections of Turnebus, professor of Greek in the Royal College; of Mercier and Quinquarboreus, professors of Hebrew and Chaldee; and of the celebrated Peter Ramus, who had greatly distinguished himself by his strenuous opposition to the philosophy of Aristotle. In addition to his other engagements, young Melville commenced the study of civil law, at that time taught by Balduinus, or Baudouin, a very eminent civilian of Paris. During the second year of his residence he had attained to such proficiency in the Greek language, that he was able to speak it with great fluency and copiousness. He left Paris in the year 1566, and repaired to the university of Poitiers to prosecute the study of law. Here, owing to his great celebrity, he was appointed a regent in the college of St Marceon, though he was only twenty-one years of age. He continued to prosecute his legal studies for three years at Poitiers; but owing to political disturbances he was ultimately compelled to seek a residence elsewhere. Leaving behind him his books and other effects, and fixing a small Hebrew Bible in his girdle, he, in company with a Frenchman, set out for Geneva. When the two pedestrians reached the gates of that city, their money was all but entirely spent; Melville, however, had the good fortune to obtain, through the influence of Beza, the professorship of humanity in the academy of Geneva, and was thus enabled to support for a time his less fortunate companion.

Geneva was at this time a most conspicuous bulwark of the Reformation. It afforded an asylum to many persecuted Protestants of eminent piety and learning. The academy of Geneva, which was a university without the name, could boast of various professors of the highest reputation. The chair of Calvin, its first and most celebrated professor of divinity, was now occupied by Beza, who was likewise a man of eminent talents, and who with his profound knowledge of theology united many of the graces of polite literature. Melville, still eager to learn, became a student under this venerable professor; and acquired a knowledge of Syriac from Bertram, the professor of oriental languages. In the year 1572 the atrocious massacre of St Bartholomew compelled many of the French Protestants to abandon their native country and seek refuge in Geneva. Melville had the good fortune on this occasion to make the acquaintance of the celebrated scholar and thinker, Joseph Scaliger, for two years professor of philosophy at Geneva. He also heard the lectures of Bonnefoy on oriental jurisprudence, who, along with Hotman, another distinguished refugee, was paid by the magistrates of Geneva for delivering lectures on civil and ecclesiastical law.

After having retained his professorship for five years, he was at length induced by the urgent solicitations of his friends in Scotland to revisit his native country. He according left Geneva in the spring of 1574; and in passing through Paris engaged in a controversy, which lasted several days, with one James Tyrie, one of the antagonists of Knox, at the college of the Jesuits. He arrived in Edinburgh in the beginning of July 1574.

Melville had already distinguished himself by his Latin poetry, and his reputation as a man of talents had reached his native country. It was about this period that he made his first appearance as an author. His earliest work was entitled *Carmen Mosis, ex Deuteron. cap. xxxii. quod ipse moriens Israeli tradidit ediscendum et cantandum perpetuo, Latina paraphrasi illustratum. Cui addita sunt nonnulla Epigrammata, et Jobi cap. iii. Latino carmine redditum. Andrea Melvino Scoto auctore*, Basileæ, 1574, 8vo. The Earl of Morton, regent of the kingdom, was desirous of retaining him in the capacity of a domestic chaplain; but he had no wish to become a courtier; and he was persuaded that his labours would be most available to his countrymen if he were placed in one of the universities. On the death of John Douglas, who had accumulated the offices of Archbishop of St Andrews, provost of St Mary's College, and rector of the university, a proposition was made for placing him at the head of the college; but on being very strongly urged to accept of a similar appointment at Glasgow, he was finally induced to give it the preference. On his installation as principal of the Glasgow university in November 1574, he found that institution in a very unsatisfactory condition. When he commenced his academical labours his only coadjutor was Peter Blackburne, who officiated as a regent, and managed the scanty revenues of the foundation. The exertions of the principal himself to elevate the teaching and improve the character of the university were quite prodigious. He initiated his students in the principles of Greek grammar; introduced them to the Dialectics of Ramus and the Rhetoric of Talæus; read with them the best classical authors, as Virgil and Horace among the Latins, and Homer, Hesiod, Theocritus, Pindar, and Isocrates among the Greeks; taught them the Elements of Euclid, with the arithmetic and geometry of Ramus, and the geography of Dionysius; read with them Cicero's Offices, Paradoxes, and Tusculan Questions, the Ethics and Politics of Aristotle, and certain of Plato's Dialogues; expounded natural philosophy; taught the Hebrew language, accompanied with a praxis upon the Psalter and books of Solomon; initiated the students into Chaldee and Syriac; and, to complete the theological curriculum, went through all the common heads of divinity, according to the order of Calvin's *Institutes*, besides giving lectures on the different books of Scripture. This course of study was completed in six years. After some time, however, he succeeded in increasing the staff of professors, and restricted himself to divinity and oriental languages. The learning, talents, and energy of Melville speedily raised this university from its ruinous condition, and secured for it the reputation of being the first seminary in the kingdom. Students were attracted from all parts of the country, and among these were not a few graduates from St Andrews, who were disposed to learn what their former masters could not teach. Various individuals who afterwards rose to eminence were here trained under his discipline. Melville's influence in advancing the literature of his native country was great and lasting; nor was it less considerable in improving the condition of the Scottish church. He was a member of the General Assembly convened at Edinburgh in March, as well as that convened at the same place in August 1575. The lawfulness of episcopacy was debated in this latter assembly; and he there maintained the negative side of the question in a speech which, as Spotswood admits, "was applauded by many." For the more mature discussion of this subject, the assembly appointed a committee of six, of which Melville formed one, who presented a report expressive of a mild but essential hostility to episcopacy. This report was approved by the assembly held in April 1576; and those bishops who had not already undertaken some parochial cure, were enjoined to select particular parishes for the exercise of their pastoral functions. This was the first step towards the abolition of diocesan episcopacy in Scotland. Of the assembly held in Magdalene Chapel at Edinburgh in the month of April 1578, Melville was chosen moderator. The Second Book of Discipline now received the sanction of this ecclesiastical judicature; and it was resolved that bishops should no longer be described as *lords*, but should be addressed like other ministers.

After a residence of six years at Glasgow Melville was removed to St Andrews, where he was installed as principal of St Mary's College, in the month of December 1580. The university of St Andrews had very recently been subjected to a salutary reform, and this college had been appropriated to the study of divinity. The office of primarius professor of divinity was then conjoined, as it still continues to be, with that of principal. Here, again, however, owing to the temporary incompleteness of the university, the enthusiastic principal, in addition to his own lectures on systematic theology, "taught learnedly and perfectly the knowledge and practice of the Hebrew, Chaldee, Syriac, and rabbinical languages." In this new situation he had to contend with new difficulties; but his superior talents and learning, with the firmness and consistency of his personal character, enabled him to overcome all opposition.

Melville took a prominent part in the subsequent ecclesiastical struggle of his country against the restoration of popery. At a General Assembly held at St Andrews in April 1582, he was again elected moderator, and assisted in drawing up a vigorous remonstrance, complaining of their grievances, and craving redress. A deputation of the members, with the moderator at its head, was named for the purpose of presenting this remonstrance to his majesty, who was then residing at Perth. It was accordingly presented to the king in council; and on its being read, the Earl of Arran asked with an angry countenance, "Who dare subscribe these articles?" "We dare," said the undaunted Melville, and immediately signed his name, the other commissioners following his example. The minions of power were overawed by their intrepidity, and dismissed them without any formal censure.

On one occasion Melville, in a public sermon, took the liberty of animadverting on certain public abuses, when the provost of the city abruptly quitted the church in the middle of the discourse, not without muttering his high displeasure at the unsparing zeal of the preacher. The gates of St Mary's College exhibited placards threatening to bastinade the principal, to set fire to his lodgings, and to expel him from the city. But in the midst of these excitements he not only continued firm and undismayed, but summoned the provost before the presbytery for contempt of divine ordinances. He was soon afterwards exposed to danger from another quarter. He was cited to appear before the Privy Council on the 17th of February 1584, to answer to a charge of having, on the occasion of a fast kept during the preceding month, uttered certain seditious and treasonable words in his sermon and prayers. Furnished with ample testimonials of his loyalty, he repaired to Edinburgh, and having appeared before the council, he entered into a full explanation and defence of the expressions which he had actually employed. The Privy Council resolved. however, to proceed against him, when he declined its jurisdiction in a written protest. On the reading of Melville's declinature the king and Arran were roused to unseemly rage; but they had to deal with a man whom the frowns of royalty could not intimidate, and he pleaded his own cause with the most unshaken firmness and resolution. In the course of his speech he appealed to the authority of the Scriptures; and unclasping a Hebrew Bible that was suspended at his girdle, he threw it on the council table, and challenged any of his judges to show that he had exceeded his instructions. He was, however, found guilty of behaving irreverently before the council and of declining its jurisdiction, and was sentenced to be imprisoned in the castle of Edinburgh, and to be further punished in his person and goods at the pleasure of the king. On learning that the place of confinement was changed to Blackness Castle, a dreary dungeon kept by a dependent of the Earl of Arran, he escaped from Edinburgh, and next day proceeded to Berwick. This rigorous treatment of so learned and eminent a man excited no small degree of popular indignation. Having obtained permission to visit London, he proceeded on his journey, bearing with him instructions from the exiled nobles who were then residing at Berwick. During the ensuing month of July he paid a visit to the universities of Oxford and Cambridge, and was received with great marks of respect. After an absence of twenty months, Melville and the banished lords returned to Scotland in the beginning of November 1585. He lost no time in using his best endeavours for the recovery of those liberties of which the church had recently been deprived. He undertook a mission to various parts of the kingdom for the express purpose of securing a united effort among his brethren, to effect a change in the ecclesiastical polity of the country.

During the absence of Melville the university of St Andrews had witnessed many vicissitudes; but in the month of March 1583 its zealous and learned principal returned to the scene of his former labours. When Du Bartas, an envoy from the King of Navarre, accompanied King James to St Andrews, they came to hear a lecture from Melville; and he pronounced an extempore discourse, which is said to have given "satisfaction to all the hearers except his majesty, who considered some parts of it as levelled against his favourite notions of church government." Aroused by the efforts made by the archbishop to induce his majesty further to encourage prelacy, the intrepid reformer, despite the threats of the king, delivered an elaborate discourse on the following day, directed against the positions of the archbishop, and characterized by great eloquence and power; on which the royal auditor condescended to deliver a speech, enjoining all to respect and obey the archbishop. The imperial disputant afterwards deigned to partake of a collation in the college, and was regaled with "wet and dry confections and all sorts of wine."

Of the General Assembly held in June 1587 Melville was elected moderator; and on the 17th of May 1590 he was present at the coronation of the queen, and recited a Latin poem which he had composed for the occasion, and which was immediately published (Στεφανίσκιον, *ad Scotiæ Regem, habitum in Coronatione Reginæ,* 17 *Maii* 1590, *per Andream Melvinum,* Edinb. 1590, 4to). His antagonist, Adamson, who died on the 19th of February 1592, had been deprived of his office, together with all its emoluments, by the king. Left to poverty and contempt, Melville hastened to pay him a visit, and not only procured contributions from his friends at St Andrews, but even continued for several months to support him from his private resources. The death of this accomplished and unfortunate prelate was speedily followed by the formal restoration of presbytery; and Melville, after being again elected moderator of the General Assembly of May 1594, subsequently accompanied the king on his expedition against the popish lords, after the battle of Glenlivet; and his majesty, who had requested their attendance, found him a very faithful and able counsellor. When an attempt was afterwards made to recal the popish lords from banishment, Melville, with other commissioners, was admitted to a private audience of the king, when, taking his majesty by the sleeve, and calling him "God's silly vassal," he proceeded to address him in a strain which was "perhaps the most singular, in point of freedom, that ever saluted royal ears, or that ever proceeded from the mouth of a loyal subject, who would have spilt his blood in defence of the person and honour of his prince." While some applaud the courage of this undaunted presbyter, others may be equally disposed to condemn him as guilty of unwarrantable insolence to his sovereign. For several years ensuing the king made repeated attempts to regulate the church according to his own arbitrary notions, but constantly found a strenuous opponent in the worthy principal of St Mary's. After repeated and fruitless endeavours on the part of the king to prevent Melville from occupying a seat in the General Assembly of the church, his majesty at last, by his sole authority, commanded him, under pain of treason, to confine himself within the walls of his own college; a sentence afterwards relaxed by the intercession of the queen, so as to permit him to move within a circuit of six miles from St Andrews.

Andrew Melville was one of the eight presbyters called to London by King James on his accession to the English throne, for the overt purpose of restoring the tranquillity of the church, but, as is confidently believed, with the secret intention of circumventing this formidable scourge of episcopacy. Melville and his colleagues, however, conducted themselves with so much firmness and skill, that they were dismissed with unequivocal marks of approbation on the part of those who were present. "The English nobility," says M'Crie, "who had not been accustomed to see the king addressed with such freedom, could not refrain from expressing their admiration at the boldness with which Melville and his associates delivered their sentiments before such an audience, at the harmony of views which appeared in all their speeches, and the readiness and pertinency of the replies which they made to every objection with which they were urged."

Before quitting the metropolis various artful but fruitless expedients were adopted for corrupting the integrity of the staunch Presbyterians of the north. They were, besides, treated to lectures on the beauties of episcopacy, and permitted to witness one of its most imposing spectacles, which only served, however, to excite ridicule in the irreverent minds of the stern presbyters, and which found vent in a trenchant epigram of Melville's (*Melvini Musæ,* p. 24, anno 1620, 4to), who was obliged to appear at Whitehall and answer for his obnoxious verses. On appearing before the king and council, Bancroft, Archbishop of Canterbury, began to expatiate on the aggravated nature of his offence, which he described as coming within the definition of treason. "My lords," he indignantly exclaimed, "Andrew Melville was never a traitor; but there was one Richard Bancroft (let him be sought for), who, during the life of the late queen, wrote a treatise against his majesty's title to the crown of England; and here is the book." Bancroft, who was totally unprepared for such an act of retaliation, sat in mute astonishment, while Melville proceeded to accuse him of profaning the Sabbath, and of silencing and imprisoning faithful preachers of the gospel for scrupling to conform to the vain and superstitious ceremonies of an anti-Christian hierarchy. He gradually advanced so near this pontiff as to shake his lawn sleeves; and calling them Romish rags, he thus continued to address him: "If you are the author of the book called *England Scottizing for Geneva Discipline,* then I regard you as the capital enemy of all the Reformed churches in Europe, and as such I will profess myself an enemy to you and your proceedings, to the effusion of the last drop of my blood; and it grieves me that such a man should have his majesty's ear, and sit so high in this honourable council." After some altercation, Melville was informed that he had been found guilty of *scandalum magnatum*, and was to be committed to the custody of the dean of St Paul's till the king should signify his pleasure as to his further punishment. On the 26th of April he was again summoned before the council. The King of Great Britain, France, and Ireland had recourse to the expedient of stationing himself in a closet where he could hear without being seen; and he received the appropriate reward of hearing himself mentioned with the utmost freedom of speech by the most undaunted of his subjects. By a most inquisitorial sentence, worthy of Rome or Toledo, he was committed as a prisoner to the Tower. His nephew, who had written an epigram on the superstitions of the church, was commanded to fix his residence at Newcastle-upon-Tyne, and not to move beyond a distance of ten miles from that town.[1] Their brethren were permitted to return to Scotland, but were each of them restricted to particular limits.

For the space of about ten months the prisoner was subjected to the most rigorous treatment; no person was allowed to visit him; he was not permitted to retain a servant, and was even denied the use of pen and ink. But his manly spirit was still unsubdued, and he endeavoured to amuse his solitary hours by composing Latin verses, which, with the tongue of his shoe-buckle, he engraved on the walls of his prison-house. From these unnecessary restraints he was at length released by the intercession of some of his friends at court, and particularly of Sir James Semple, but the king could not yet be induced to open the doors of his prison. At the expiration of four weary years he was released at the intercession of the Duke of Bouillon, who invited him to fill the chair of biblical literature in the Protestant university of Sedan. He was now in the sixty-sixth year of his age, and had long filled an honourable and conspicuous station in his native land, to which he felt that strong attachment which his countrymen so generally feel. It was accordingly with some degree of reluctance that the brave old presbyter prepared for this voyage to France. He embarked, however, on the 19th of April 1611, and having spent a few days at Rouen and Paris, he arrived at Sedan in the course of the ensuing month. In this university he was associated with several of his countrymen, which served to lighten his banishment; yet he did not cease to cherish some lingering though faint hope of being permitted to deposit his bones in the land of his fathers. His naturally vigorous constitution had been impaired, however, by his protracted imprisonment; and he terminated his eventful life at Sedan in the year 1622, at the age of seventy-seven.

Melville was small in stature, and was alike conspicuous for his vivacity of body and mind. His elasticity of spirit, which he appears to have retained till the last years of his life, was accompanied with a warm and impetuous temperament, which, however, was free from all personal malignity. From his early youth he was distinguished by fervid and consistent piety. He was a man of the most unblemished integrity; nor did his enemies, who were sufficiently numerous, venture to charge him with sordid or selfish motives of conduct; their accusations chiefly relate to his want of personal reverence for the king, and to his want of veneration for bishops. In private life he appears to have been very amiable and affectionate: if his indignation was easily roused, it was also easily appeased. Melville was unquestionably possessed of very uncommon talents, and he had acquired an ample and varied store of erudition. Such was his indifference to literary reputation, however, that although so capable of writing in prose or verse, he committed very few works to the press. In the excellent *Life of Andrew Melville* by Dr M'Crie, 2 vols. 8vo, 1819, will be found an enumeration of his works, to which may be added a MS. *Commentarius in divinam Pauli Epistolam ad Romanos, auctore Andrea Melvino Scoto.*

MELVILLE, *Sir James*, whose name is familiarly known to the readers of Scottish history, was born in the year 1535. He was the third son of Sir John Melville of Raith in Fifeshire, by his wife Helen, the eldest daughter of Sir Alexander Napier of Merchiston. At the age of fourteen he had the misfortune to lose his father, who, having espoused the Reformed doctrines, was, at the instigation of Archbishop Hamilton, brought to the scaffold at Stirling, convicted of high treason. The archbishop having found means of seizing upon his estate, Melville's widow and children were reduced to a state of penury. Through the influence of the queen-regent, young Melville was attached to Monluc, Bishop of Valence, as a page of honour. After a series of curious adventures, the young Scot reached Paris, where, during his master's absence at Rome, he was left to improve his education. Young Melville having accidentally come under the notice of Montmorenci, the great constable, after obtaining the bishop's consent, took him into his service. In this position he witnessed several campaigns in France and Flanders during 1553. The kindness of his patron procured him a pension from the king during the following year.

In 1557 he bore arms at the battle of St Quentin, where the constable's army was totally defeated, and he was himself wounded and taken prisoner. He attended the constable during his captivity; from which he was delivered by the treaty of Cateau-Cambresis, concluded in the year 1559. In the course of the same year the king, at Montmorenci's suggestion, sent him on a secret mission to Scotland, where, under the pretext of paying a visit to his relations, he was instructed to use his best endeavours for ascertaining the real views of the Prior of St Andrews and his adherents. During Melville's absence the constable, his master, had the misfortune to kill his sovereign, Henri II., in a tournament, which led to his removal from the court. Melville, although received with the greatest kindness, judged it expedient to try his fortune in another country, and he now directed his views towards Germany. He entered the service of the elector palatine, and was employed by that prince on various diplomatic missions. In company with the elector's second son Casimir he visited France during 1561; and he there made a tender of his services to Queen Mary, who was on the eve of returning to Scotland. She received him very graciously, and urged him "when he wes to retire him out of Germany, to com hame and serue hir Maieste, with friendly and fauorable offers."

Having received communications from Moray and Maitland, requiring him, in the name of their royal mistress, to return home for the purpose of being employed in some affairs of consequence, Melville took leave of the elector palatine, and after executing a commission to the Queen of England with which he had been intrusted by his German master, he directed his steps towards Scotland, and presented himself to Mary at Perth on the 5th May 1564. The Queen of Scots received him graciously, and engaged him in her service, bestowing upon him a pension of a thousand marks.

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[1] James Melville was afterwards permitted to reside at Berwick, where he died on the 19th of January 1614, in the fifty-ninth year of his age, and the eighth of his banishment. He was twice married, and left several children. He appears to have been an upright and disinterested man: his zeal, less fiery than that of his uncle, was equally uniform and consistent, nor did the offer of a bishopric shake his attachment to presbytery. His talents were much inferior to those of his uncle. He is the author of various works in the Latin and Scottish languages. His Diary, recently printed for the Bannatyne Club, contains much curious information relative to the ecclesiastical and literary history of that age.

After an interval of a few months, Melville was intrusted with an embassy to the Queen of England. Of his proceedings on this occasion he has given a circumstantial and characteristic account, in which the characteristic weaknesses of Elizabeth are very prominently displayed. He continued his attendance at court after the queen's marriage with Darnley, and must sometimes have had a difficult and delicate part to perform. On the birth of a prince, 19th June 1566, he was instantly despatched to convey the intelligence to Elizabeth, and returned to his royal mistress with a choice collection of court gossip respecting the serious manner in which Elizabeth took to heart the news which had just come from Scotland of the birth of a prince. During the following year, when Mary was intercepted by the Earl of Bothwell, he was among her other attendants, and along with her was conducted to Dunbar Castle, but was only detained for a single day. Amidst the civil commotions which succeeded he appears to have pursued a prudent and cautious tenor of conduct, and to have abstained from involving himself too deeply with either of the adverse factions. He had adhered to the queen till she was committed to Lochleven Castle. During the eventful regency which ensued Melville had some concern in public affairs; and after the king received the reins of government into his own hands he was appointed a gentleman of the bed-chamber, and a member of the Privy Council. He was not, however, acceptable to James's favourite, the Earl of Arran, through whose influence his name was in 1584 expunged from the list of privy councillors. He did not entirely lose the king's favour, but was soon afterwards consulted on various occasions; and was in 1590 attached to the queen's household.

When the king succeeded to the crown of England his majesty was anxious to retain his services, but he being desirous to "spend the remainder of his days in contemplation, begged his Majestie's permission thereto." He died on the 13th of November 1617, at the mature age of eighty-two. (Wood's *Peerage*, vol. ii., p. 112.) From the eldest brother of Sir James Melville is descended the noble family of Leven and Melville.

Melville employed some portion of his declining age in writing memoirs of his public life; and the work was published by his grandson, George Scott of Pitlochie, sixty-six years after the death of the author. *The Memoirs of Sir James Melvil of Hal-hill; containing an impartial Account of the most remarkable Affairs of State during the last Age*, &c., London, 1683, fol.; Edinburgh, 1735, 8vo.; Glasgow, 1751, 12mo. The fidelity of the editor, however, was liable to strong suspicion, which was naturally augmented by the consideration that no early copies of the memoirs could be traced in any public or private library. But a manuscript, apparently in the handwriting of the author, was at length discovered in the collection bequeathed to the Rose family by the Earl of Marchmont. From this manuscript the work was printed for the Bannatyne Club: *Memoirs of his own Life by Sir James Melville of Halhill.* M.D.XLIX.–M.D.XCIII.; Edinburgh, 1827, 4to. Melville's memoirs, in this authentic form, are a most valuable accession to the stock of original materials for Scottish history.

MELVILLE BAY, an inlet of Baffin's Bay, on the coast of Greenland, Lat. 76. N., Long. 60. to 64. W. It was from this bay that the last despatch was received from the unfortunate expedition of Sir John Franklin, July 1845.

Melville Island, an island lying off the N. coast of Australia, between 11. 8. and 11. 56. S. Lat., and 130. 20. and 131. 24. E. Long. It is separated from the mainland on the E. by Dundas Strait, which is 15 miles in breadth, and on the S. by Clarence Strait; while on the W. it is separated from Bathurst Island by Apsley Strait, 46 miles in length, and varying from 1½ to 4 in breadth. The coasts of the island, on all sides but the N., are high, and in many places bold and precipitous; but on the N. the coast is low, and abounds in shallow bays. The whole island is well wooded, and in some places very thickly, except on the W. coast, where the trees are few and stunted, by reason of the N.W. monsoon. The height of the central part is 100 or 130 feet; and throughout the whole island vegetation is luxuriant, and many sorts of timber, useful for carpentry and shipbuilding, are obtained here. In all the creeks of Melville Island alligators abound; and turtles are found in great numbers on all the coasts, except that of Apsley Strait. The animals found in the island closely resemble those of Australia. The climate from October till April or May is unhealthy, on account of the excessive heat and moisture of the atmosphere. The N.W. monsoon begins about November, and rain falls in great abundance during all the hot season. From May till September the weather is dry and pleasant, though the heat even then is great. The inhabitants are divided into small tribes, and lead a wandering life, being chiefly employed in hunting. They are not much inclined to intercourse with Europeans.

MEMEL, a seaport of E. Prussia, in the government of Königsberg, is situated at the entrance of a large inlet of the Baltic called the Kurische Haff, near the mouth of the Dange, 74 miles N.N.E. of Königsberg; Lat. of lighthouse 55. 43. 7. N., Long. 21. 6. 2. E. The town consists of three parts—the old town, the new town, and Frederick's Town; besides several suburbs. It was surrounded by walls in the time of the Teutonic knights, and is still fortified, having a citadel with four bastions, built in 1250, and part of which is now employed as a prison. Memel contains two Lutheran churches, one Calvinistic, and one Roman Catholic church, a synagogue, several schools and benevolent institutions, two arsenals, an exchange, and a theatre. The harbour, which is spacious and secure, is obstructed by a bar at the entrance of the Kurische Haff; where the depth of water is never more than 18, and sometimes as low as 13 feet; so that large vessels are obliged to load and unload in the roads. The harbour is commanded by the citadel; and at the entrance stands the lighthouse, 128 feet high, with a very brilliant stationary light, which is visible to the distance of 20 miles. The principal articles of manufacture are woollen cloth and soap; and there are also in Memel breweries, distilleries, shipbuilding yards, &c. The position of the town on the Baltic, and its proximity to the Russian frontier, render it a place of considerable trade. The following is an account of the number and tonnage of the vessels which have entered and left the port from 1851 to 1854:—

	Entered.		*Cleared.*	
Year.	Ships.	Tonnage.	Ships.	Tonnage.
1851	1104	143,210	1198	141,808
1852	740	92,083	760	97,132
1853	984	129,591	1007	134,380
1854	1766	208,984	1570	183,266

The number of vessels belonging to Memel was in 1855, 85, and in 1856, 88. The principal exports are,—timber (chiefly oak and fir), corn, hemp, flax, oil, wool, hides, tallow, &c.; and the imports consist of salt, coal, herrings, cutlery, cotton, yarn, &c. The town was partially destroyed by fire in 1854. Pop. 10,769.

MEMMI or **Di Martino, Simone**, a celebrated Italian painter, was born about 1285 at Siena. According to Vasari, he was a pupil of Giotto, and in 1298 was engaged under that master in the mosaic of the Navicella at Rome. But as Memmi was then only fourteen, Vasari's account has been doubted by Rumohr, Lanzi, and others. He was, however, a close student of Giotto's works, and at an early age painted the portico of St Peter's at Rome in the style of that artist. So notable was this performance that he was immediately invited to the papal court at Avignon. Here he became intimate with Petrarca; and the respective arts of the painter and the poet were employed to commemorate their mutual friendship. Memmi painted the portrait of Laura, the lady-love of his friend the poet; Petrarca, in return, immortalized Memmi in two of his sonnets. After producing at Avignon many good pictures, both in fresco and distemper, Memmi returned to Siena, and was employed in the decoration of the palace and cathedral of that city. Invited to Florence by the general of the Augustines, he painted in the chapter-house of Santo Spirito a masterly and elaborate picture of the Crucifixion. Soon after his return to Siena his last illness attacked him. He contrived, however, to travel to Avignon, and there he died in 1344.

A few of Memmi's numerous productions still exist. In the Campo Santo at Pisa are his stories from the life of San Ranieri, and his famous "Assumption of the Virgin." His histories of Christ, San Domenico, San Pietro Martire, and part of his history of the Preaching Friars, are found in the chapter-house of the Spanish Friars at Florence. Petrarca's manuscript copy of *Servius on Virgil*, which is preserved in the Ambrosian Library of Milan, contains a miniature of exquisite conception by Memmi. It represents Virgil engaged in composition, and raising his eyes heavenward to catch the ray of inspiration. A shepherd, a husbandman, and a warrior standing before him intimate the respective subjects of the Bucolics, Georgics, and Æneid. The function of the critic is indicated by a representation of Statius drawing aside a veil of delicate transparency.

"Memmi's works," says Vasari, "prove that he possessed great power of imagination, and was well versed in the best methods of composing his groups in accordance with the manner of those days." A great tribute is paid to him by Petrarch: "I am acquainted," he says in one of his letters, "with two illustrious painters,—Giotto the Florentine, of great fame among moderns, and Simone of Siena." (Vasari's *Lives of the Painters*, and Lanzi's *History of Painting*.)

MEMMINGEN, a town of Bavaria, circle of Swabia, situated on a tributary of the Iller, 43 miles S.W. of Augsburg. The town is walled, and contains a handsome town-hall, an arsenal, barracks, several churches, schools, hospitals, &c. It has manufactures of woollen, cotton, and linen fabrics, stockings, ribbons, tobacco, iron and copper wares, &c.; and there is a considerable trade in salt, wool, corn, and the various manufactures of the place. Memmingen is noted as the scene of a victory gained by the French under Moreau over the Austrians, 10th May 1800. Pop. 7200.

MEMNON, the *Resolute* or *Steadfast* (from μένω). 1. The son of Aurora and Tithonus, a hero of the Trojan war. Homer mentions him in the *Odyssey* as remarkable for his beauty, and alludes to his having slain Antilochus, the son of Nestor. (*Odyss.* iv. 188, xi. 521.) Hesiod speaks of him as king of the Ethiopians. (*Theog.* 984-5.) Later writers give us much fuller accounts of Memnon; but it must not be therefore concluded that he was not until then celebrated; for Arctinus of Miletus, who is assigned to the middle of the eighth century B.C., wrote a poem, *Æthiopis*, of which his history probably formed the main object. (Heyne, *Excurs.* xix., ad *Æn.* i.) The story of Memnon is variously told by the later writers, all agreeing that he came to the aid of Priam with a force of Ethiopians; and was slain by Achilles. (*Dict.* iv. 4, vi. 10; *Quint. Smyrn.* ii. 30, *et passim*; *Tzetz. Posthom.* 235; *Paus.* x. 31; *Apollod.* iii. 12, sect. 4; *Diod. Sic.* ii. 22, iv. 75, &c.) Some call him a leader of Indians as well as Ethiopians, or consider the two identical. Those additions which make Memnon to have been sent by Teutamus, a king of Assyria, whose vassal his father was, and which connect him with Susa, probably result from an attempt to gain a synchronism of Greek and Assyrian history. Any direct endeavours to find a place for Memnon in Assyrian and Egyptian history, which might at first sight be ascribed to native sources, are especially important with reference to his story and his connection with various places and monuments. In the cases of both countries they appear to be wholly of Greek origin, or at least of an origin external to the nations to whose histories they have been attached. The fragments of Assyrian history preserved by ancient writers contain no direct mention of Memnon; but in one list there is an evident reference to him. In it occurs the name of Teutamus, with in one version the addition, in a very corrupt form, that in his time Troy was taken by the Greeks. (Cory's *Ancient Fragments*, 2d ed., p. 77.) The character of the whole list, which consists of Assyrian, Persian, and Greek names, strung together so as to fill up a certain period, makes any further examination needless. There does not seem to be any other mention of Memnon which could at the first view be even conjecturally assigned to an oriental source. The supposed Egyptian reference to Memnon of the same kind is equally unauthoritative, although found in a far different document. The list of dynasties, epitomized from the lost work of Manetho, the Egyptian historian, contains, under some reigns, historical observations which are not always original. (See MANETHO.) Among these notices is one relating to Memnon. It is said of Amenôphis, the seventh or eighth sovereign of the eighteenth dynasty, the Amenoph III. of the monuments, that he is considered to be Memnon and the speaking stone. (*Anc. Frag.*, p. 116, 117.) It was a statue of this king that was celebrated as the Vocal Memnon; but there is strong reason to suppose that it did not become famous until long after Manetho's time; and the Egyptians, as appears from the inscriptions of visitors on the statue, took no interest in the vocal phenomenon. It is reasonable, therefore, to regard the notice in the lists, like others of a similar character, as not virtually Egyptian, and added by an epitomizer or chronologer. The examination of the inscriptions of the statue has however shown, as positively as can be on evidence of this kind, that the connection of Memnon with Egypt was of Greek origin. Thus the old Greek tradition or myth is our only authority. If we carefully consider it, we can scarcely do wrong in concluding Memnon to be a mythological personage. Whatever view we take of the Trojan war itself; whether we consider it, with some, as purely mythological; or, with others, as having a vague historical basis; or, again, with others, as having a sure historical basis; we must be ready to admit that most of the heroes are mythical. If we suppose, as seems most reasonable, some of those from whom descent was claimed by contemporaries of Homer to be personages whose memory was preserved in tradition, we may fairly argue the reality of not a few Greek heroes; but we could scarcely apply this argument to the case of foreigners who were not even Trojans. The Greek form of Memnon's name also, like Agamemnon, is somewhat against his reality, although it should be noted that its root is found in the Semitic languages and in Egyptian (see HIEROGLYPHICS, vol. xi., p. 372); so that it might be similar to an original name both in sound and in signification. If, however, we hold that there was, at about the time to which the Trojan war has been usually assigned, a great struggle between the Greeks and the Asiatics in the Troad, we find strong reason for supposing some such expedition from the East as that of Memnon. The progress of modern research is tending to show the truth of the broad outlines of many such traditions, as it indicates the general state of the countries to which they refer. The power of the Assyrian empire about this period was so great, that it is scarcely possible that a war of any length and importance could have been waged on the western coast of Asia Minor without its interference; and Memnon—who in the older form of the story is always an eastern Ethiopian, as the son of Aurora should be, and not a western—may with his forces be taken to represent some such aid from Assyria. It was not unnatural, that as in subsequent times Egyptian sites were in some manner connected with Memnon by Greek travellers or their guides, he should have been associated by later authors with the western Ethiopians also,—unless, indeed, this last idea gave rise to a search for Memnonian remains in Egypt. The twofold geographical division of the Ethiopians was known to Homer and Herodotus, is indicated in the Scriptures, and has been, last of all, confirmed by the cuneiform inscriptions, and, we may venture to say, by ethnology also. It is worthy of remark, that the chief individual identified in Egypt with Memnon appears in his race to have singularly corresponded to the Memnon of the later writers, since there is reason to believe him to have been sprung from the eastern as well as the western Ethiopians; but this agreement can hardly be considered as more than fortuitous.

Although tombs of Memnon, and structures or places called after him, were shown in various countries, there are but two which can be considered of high importance,—the Acropolis of Susa, called the *Memnonium* or *Memnonia*, and the great western suburb of Egyptian Thebes, bearing the latter name. The former town is called by Herodotus Memnonian (v. 54), doubtless from the Acropolis, which was probably its most ancient part. Pausanias alludes to the thickness of its walls (lib. iv., c. xxxi., § 5). The suburb of Egyptian Thebes called *Memnonia* (τὰ Μεμνόνεια) is generally held to have included all the buildings on the western bank of the river; but Sir Gardner Wilkinson considers it to have been only a part of Pathyris, the "Libyan suburb." (*Modern Egypt and Thebes*, vol. ii., p. 137.) It must have been, however, the most important quarter. Its name can scarcely be said to be of Greek origin, for it is as old as the time of Ptolemy Physcon, when a Greek identification of its edifices, or of the famous vocal statue, would not have been able to give a name to part of a town so thoroughly Egyptian as Thebes, though it could easily originate a corruption. We have only to remember the manner in which purely native names by a slight change were connected with Greek mythology or tradition, as in the cases of Canopus and Antæopolis, to see how easily a name resembling Memnonia would have been converted by the Greeks into that word.

The Vocal Memnon is the northernmost of two seated colossi, representing Amenoph III., placed in the approach to a temple now utterly ruined, in the midst of western Thebes. The temple appears to have been wholly raised by the same sovereign; and if any structure were specially called by the Greeks a Memnonium, it must have been this; although it is more probable that all the temples, or at least the larger ones, in the quarter bore this name. It is a common error to call the temple of Rameses II., or the Rameseum of El-Kurneh, the Memnonium. The height of each of the two colossi is about 47 feet, and they rest upon pedestals about 12 feet high. Greek and Latin inscriptions on the Vocal Memnon, chiefly on the legs, attest that visitors have heard the voice of Memnon, and paid this work of reverence to him, for they are *proscynemas*. The inscriptions record the visits of Hadrian and the Empress Sabina and their suite, of eight governors of Egypt, and several other persons holding office. The number of inscriptions known is seventy-two, of which thirty-five bear dates. The earliest is of the ninth year of Nero; the latest of the reign of Septimius Severus. We learn from them, and the concurrent testimony of ancient writers, that the vocal phenomenon did not occur, or at least did not attract attention, until after the Roman conquest, that apparently it ceased at the time of Severus, and that it was an object of veneration to the Greeks and Romans, and not to the Egyptians. At this time the statue was broken in two; and it was from the portion remaining in its place, the lower half, that the sound seemed to come. Some of the inscriptions agree with Pausanias in ascribing the overthrow of the statue to Cambyses; but Strabo heard that it had fallen through an earthquake. The former opinion seems on the whole the more reasonable, since it has the weightier evidence on its side, and because such a convulsion as would suffice to break a monolithic statue would be far more violent than any recorded to have happened in Egypt. Yet there are traces of the effects of earthquakes in that country, and probably at Thebes; and it is not to be forgotten that Eusebius relates that one which occurred B.C. 27 destroyed this town. It is to this earthquake that Letronne ascribes the overthrow of the statue. The upper part was subsequently restored, and it is not improbable that this was done by order of the Emperor Septimius Severus, as the same savant conjectures. The sound is said to have resembled the twanging of a harp-string or the striking of brass. The ancient writers who speak of the time of its occurrence say that it was at sunrise, when the sun's rays first struck the statue; but the inscriptions show that it did not always occur until some time, often a considerable time, after sunrise. As to the cause of the sound opinions are much divided, and mainly with respect to its genuineness. Sir Gardner Wilkinson argues it to have been an imposture, and cites the remarkable fact that one of the stones of which the upper part is formed, just above the main fracture, when struck gives a metallic sound. (*Mod. Egypt and Thebes*, vol. ii., p. 160-162.) M. Letronne considers that the sound cannot have been the result of an imposture, and shows that similar sounds have been heard to proceed from stones under the influence of the sun's says. Several of the writers of the great *Description de l'Egypte* frequently heard such a sound, always shortly after sunrise, apparently issuing from one of the roof-stones of the granite sanctuary of the temple of El-Karnak. Mr Lane also states (in his MS. journal) that in the neighbouring temple, called the Rameseum of El-Kurneh, he heard for several successive days "a single, distinct, musical sound, like that produced by a harp-string, evidently proceeding from some stone above him." This occurred shortly after noon. He supposes that at this time the stone became exposed to the sun, and suddenly expanding by the increase of temperature, produced the sound. There is therefore a possible explanation of the voice of Memnon, which, if an imposture, could scarcely have been successfully maintained in such a position for two centuries. It is easy to understand how the Greeks, finding a statue which gave forth a musical sound when touched by the solar rays, in a place called Memnonia, or having a name nearly resembling this, supposed it to represent Memnon, who thus saluted his mother; and the Egyptian priests would have readily encouraged the delusion; or they may have even originated the idea, to impose upon the Greeks. —In these observations on the Vocal Memnon we have mainly followed M. Letronne's *Statue Vocale de Memnon*, an essay which, notwithstanding some faults of strained reasoning, is the most learned and satisfactory one that has been written on this curious subject.

2. *Memnon* the Rhodian, a Greek commander in the Persian service. At the time of Alexander's invasion he governed the west coast of Asia Minor. The battle of the Granicus was fought against his advice, and he was afterwards invested with the entire command of the west of Asia. He defended Halicarnassus with great skill and obstinacy, and when it was no longer tenable crossed to Cos. Having large supplies of money from Darius, he collected a mercenary force, and projected the invasion of Greece. After several successes in the subjugation of the islands, he

died at Mytilene B.C. 333. He appears to have been the only general in the Persian service capable of offering any serious resistance to Alexander.

3. *Memnon*, a governor of Thrace, who made a revolt while Alexander was in the East, which was soon suppressed by Antipater.

4. *Memnon*, a Greek historian of the Roman period, probably of the first or second century of the Christian era. He wrote a history of the town of Heraclea in Pontus, part of which Photius has preserved in a somewhat copious abstract. His historical accuracy is much to be commended, but he shows great ignorance of geography. These remains are given in the *Fragmenta Historicorum Græcorum* (Didot), vol. iii., pp. 525-558. The best separate edition is that of J. Conr. Orelli, Leips. 1816. (R. S. P.)

MEMPHIS, an ancient city of Egypt, the site of which is on the W. bank of the Nile, about 10 miles S. of Cairo. Its name, in Egyptian, was *Men-nufr*, signifying the "good abode," or, as some think, the "abode of the good one," or *Osiris*. In Hebrew it was called *Moph* or *Noph*. The sacred name was *Ptah-ee*, "the abode of Phthah," or Vulcan, its chief god. The foundation of Memphis is ascribed to Mênês, the first king of Egypt, who reigned about B.C. 2700. On the division of the kingdom not long afterwards, it became the capital of successive Memphite dynasties, which appear to have lasted, with one considerable break, through about a thousand years. Under the Fourth Dynasty, which was the second Memphite one, the most famous of the pyramids near the city were raised. During this long period it seems to have been the most important city of Egypt. When the whole country was united under one Theban sovereign (B.C. cir. 1525), Memphis became the capital of Lower Egypt, and probably had a larger population than the kingly residence, Thebes. Under the Lower Egyptian dynasties that ruled after the Theban line Memphis recovered much of its importance, and was virtually the chief town until the foundation of Alexandria. After this it was the native capital for some time, and second only to the new city. It was finally ruined by the foundation of El-Fustát, upon the opposite bank, by the Arab conquerors.

The most important edifices and monuments of Memphis were the temple of Phthah, the Serapeum, the burial-place of the bulls Apis, and the pyramids. The first of these was the chief temple of the place; and successive kings from the earliest times made additions to it. Its site is marked by but scanty remains, for it has been used as a quarry, like the other Memphite monuments, by the Mohammedan inhabitants of the successive Arab capitals. The ruins of the Serapeum, and the vast subterranean sepulchre of the bulls Apis in connection with it, have been lately discovered by M. Mariette. The pyramids, which were the tombs of kings, and apparently of other royal personages also, extend along the edge of the desert behind Memphis for several miles N. and S. Around them are the tombs of subjects. (For further information see the article EGYPT.) (R. S. P.)

MEMPHIS, a town in the state of Tennessee, Shelby county, North America, pleasantly situated on the Mississippi, just below its confluence with the Wolf River, 420 miles below St Louis, and 209 miles W.S.W. of Nashville. The town is built on a bold promontory, 30 feet above the river; while below, a bed of sandstone running into the river forms a convenient landing-place. The town has a large esplanade in front, and many very handsome buildings, of which the chief are,—six or seven churches, an academy, a medical college, two banks, &c. Memphis is a place of great trade and growing importance; while shipbuilding and manufactures of iron, cotton, and ropes, are also carried on. Pop. (1850) 8841; (1853) about 12,000.

MENA, JUAN DE, a Castilian poet of considerable merit, was born at Cordova about 1411. He was early left an orphan; and at the age of twenty-three, as Romero naïvely informs us, he first gave himself to "the sweet labour of good learning," pursuing a regular course of study at Salamanca and Rome. On his return he was made a governor of his native city; and his learning and skill as a poet soon gained for him admittance at the court of Juan II., where he secured the friendship of the veteran soldier and elegant poet the Marquis of Santillana, and afterwards received the appointment of Latin secretary to the king and historiographer of Castile. He became ultimately a kind of poet-laureate. If a battle was won, Juan de Mena had to celebrate the victory in verse; if a pacification took place between the king and his son, the poet recorded the restoration of harmony in appropriate song; and if the Constable de Luna received a slight wound, Juan was ready with his *quintillas* to soothe the pain. He found friends also among eminent personages in Portugal. The Infante Don Pedro, himself a versifier of some note, made the acquaintance of Juan while in Spain, and on his return to Lisbon addressed him in tolerable verse, and afterwards wrote a skilful imitation of the Spanish poet's *El Laberinto*. De Mena died suddenly in 1456 at Torrelaguna, where Santillana, his fast friend and patron, wrote his epitaph, and erected a beautiful monument to his memory, which stands to the present day. Some of De Mena's shorter effusions are extremely pleasant and amusing; but the greater number of his minor poems are full of affectation and fashionable conceits. His poem of the *Seven Deadly Sins*, although of grave pretensions, is but a dull allegory full of pedantry and false metaphysics. The *Coronation*, written in honour of his noble patron the Marquis of Santillana, is a sort of light parody on the *Divina Comedia* of Dante, and while an improvement on his previous poem, is nevertheless overloaded with unprofitable learning. The descriptive passages, however, are often admirable, and the versification is smooth and flowing. His long poem, the *Labyrinth*, or *The Three Hundred*, the composition of which was spread over a large portion of his life, was designed to teach, by vision and allegory, the duties and destinies of man, and is written in direct imitation of Dante's great work. Of the historical portraits introduced into the poem, the best are those of the poet's countrymen and contemporaries. Passing by the courtly flattery paid to the king and the constable, there are occasionally lines of uncommon power and tenderness, recording the premature fate of some noble Spaniard, such as the Count de Niebla. This poem met with great admiration at court; it was submitted to his majesty piecemeal as it was composed, and had the honour to receive a correction from the royal pen. Some have accorded to De Mena the title of the "Spanish Ennius," a distinction which may be considered generous, but can hardly be called just. He has always had a respectable position with his countrymen, if he cannot be considered absolutely popular. The most elaborate editions of his works are those of the learned Hernan Nuñez de Guzman, with a comment, 1499; and of the eminent scholar, Francisco Sanchez de las Brozas, commonly called El Brocense, also with a *glosa* or comment, 1582. These editions have been frequently reprinted. The principal materials for the Life of Juan de Mena are to be found in the verses of Francisco Romero, in the *Epicedio en la Muerte del Maestro Hernan Nuñez*, 1578, at the end of the *Refranes de Hernan Nuñez*. (Ticknor's *Hist. of Spanish Lit.*, vol. i., 1849.)

MÉNAGE, GILLES, "the Varron," according to Bayle, "of the seventeenth century," was the son of the Avocat du Roi, and was born at Angers on the 15th August 1613. A tenacious memory and a keen desire for knowledge carried him speedily through his course of studies, and at the early age of nineteen he assumed, in accordance with the wishes of his father, the advocate's gown. But his early developed bias towards literature was irrepressible; and after practising at the bar in Angers, Paris, and Poitiers, he abandoned the profession in disgust, and entered the church. Soon afterwards his promotion to some sinecure benefices enabled him to devote all his time to his favourite pursuit. His varied accomplishments introduced him to the most select literary society, and in no long time he was received into the family of Cardinal de Retz. But Ménage was too self-willed for a *protégé*. His caustic wit and sarcastic humour were exercised without any compunction on the political creatures of the cardinal, and his unwillingness to soothe the vanity he had wounded aggravated the offensiveness of his conduct. Accordingly, he was forced to leave the house of his patron after a few years. He retired to a dwelling of his own in the cloister of Nôtre Dame, and there he began to gather around him on Wednesday evenings those literary assemblies which he called *Mercuriales*. About this time he might have been admitted into the French Academy had he not preferred to ridicule the dictionary of that body in his *Requête des Dictionnaires*. The latter part of Ménage's life was embittered by the attacks of those authors whom his ill-tempered satire had provoked. He died on the 23d July 1692. So unrelenting were his enemies that they made even his death a subject for their satirical wit. Of the voluminous works of Ménage the following are the most important:—*Dictionnaire Etymologique*, or *Orignes de la Langue Française*, fol., 1694, and 2 vols. fol., Paris, 1750; *Origini della Lingua Italiana*, fol., Geneva, 1685; an edition of Diogenes Laertius; *Anti-Baillet*, 8vo, Paris, 1685; *Juris Civilis Amœnitates*, 8vo, Paris, 1667; and *Poemata Latina, Gallica, Græca, et Italica*, 12mo, Amsterdam, 1687. After his death *Ménagiana* was published in 2 vols. in 1693–94, and afterwards in 4 vols. in 1715.

MENAI STRAIT, an arm of the sea in North Wales, separating the island of Anglesea from the county of Carnarvon, and extending from N.E. to S.W. to a length of about 14 miles, with a breadth varying from 200 yards to 2 miles. The navigation of this strait was formerly impeded by dangerous rocks, many of which, however, have been removed, and ships, especially those with a tonnage of less than 100 tons, now pass through in safety. The Menai Strait is chiefly remarkable for the two bridges by which it is spanned. The Menai Suspension Bridge, by Telford, was begun in 1819 and opened in 1826. It is of a very elegant form, and is supported by two piers, the distance between which is 550 feet, and the whole roadway, which is carried over four arches on one side and three on the other, has a length of 1000 feet, and a breadth of 30 feet. The height of the bridge above the level of high-water is 100 feet, and the total suspending power of the bridge, exclusive of its own weight, is calculated at 1527 tons. The cost of the erection was L.120,000. The Britannia Tubular Bridge is a still more wonderful erection. It was built for the Chester and Holyhead Railway by Stephenson, and was completed in 1850, after having been in the course of construction for four years. Owing to the necessity that it should be 100 feet above the water throughout, it was impossible to construct the bridge in the usual way with arches; and on account of the vibration to which it would be liable, the suspension principle was not employed. It was therefore constructed of tubular beams of iron, by means of which the greatest amount of strength with the least weight was obtained. These beams form eight large tubes, which rest upon three towers in the sea and an abutment on the land on each side. The whole length of the roadway is 1841 feet, and its height above high-water is 101 feet, while the total height of the central tower is 230 feet. The weight of all the tubes is nearly 11,000 tons, being more than that of four line-of-battle ships fully equipped; and the cost of the whole was L.621,865. (See IRON BRIDGES, vol. xii., p. 607.)

MENAM, or MEINAM, a river of Siam, rises in the Chinese province of Yun-nan, flows southwards through the centre of Siam, and after traversing for about 800 miles a rich and well-cultivated country, discharges itself into the Gulf of Siam. It is the most important river in Siam, and its name signifies, in the language of the country, "mother of waters." The Menam is navigable as far up as Chiang-mai, in the Laos country, but its course is frequently interrupted by rapids and falls. At certain seasons it overflows its banks,—a circumstance which contributes greatly to the fertility of the neighbouring land, and to the facility of communication between different parts. On the banks of the Menam stand the ruins of Ayuthia, the ancient capital, and the city of Bankok, which is the chief town.

MENANDER, the most eminent poet of the new comedy in Greece, was the son of Diopeithes and Hegesistrate, and belonged to the *demus* of Cephissia. It is generally agreed that he was born in 342 B.C., the same year in which his father commanded the Athenian forces in the Hellespont against Philip of Macedon. He had the advantage of receiving his education from his paternal uncle, Alexis the comic poet, and Theophrastus the philosopher. An intimate friendship which he formed at an early age with Epicurus may account for much of the tone of his subsequent works. Menander's first play, entitled 'Οργή, was exhibited in his twenty-first year, and gained a prize. Not so successful were the majority of his after efforts. His genius scorned to stoop to the gross jesting that was so palatable to the mob; and accordingly, out of more than a hundred comedies which he composed, only eight won the palm. Yet the popular sentence was reversed by a band of select admirers, including Ptolemy, the first Greek King of Egypt, and Demetrius Phalereus. So intimate, indeed, was he with the latter, that on the expulsion of that eminent statesman from Athens, he with difficulty escaped being put to death. Menander had an estate at Piræus; and it is said that he was drowned while swimming in the harbour of that place in 291 B.C. The Athenians erected a tomb to his memory not far from that of Euripides. His statue was also placed in the theatre; an honour, however, which was conferred upon too many to be of much value.

Only some fragments of Menander's numerous plays remain. They were lately printed by Meineke in the fourth volume of his *Fragmenta Comicorum Græcorum*, 8vo, Berlin, 1841. They were also published, with a Latin version by Dübner, as an appendix to the *Aristophanes* of Didot's *Bibliotheca Scriptorum Græcorum*, 8vo, Paris, 1840. Many of them have been translated into English by Cumberland in the *Observer*.

Menander was the first that established the superiority of the new comedy over the old. Clearly perceiving that every form of the drama ought to be a representation of nature, he abolished the use of the chorus, and changed comedy from a satire upon persons into a description of manners. He subdued the boisterous mirth of the old comedy, and by introducing occasionally the deep earnestness of tragedy, rendered his incidents at once more impressive and more life-like. So exquisitely faithful, indeed, were his delineations from nature, that Aristophanes the grammarian exclaimed in quaint admiration, "O Menander! O Life! which of you two copied from the other?" The estimation in which Menander was held by the ancients is indicated by the number of his imitators. Among his countrymen, Alciphron and Lucian borrowed from him. Among the Romans the best writers of comedy were often the closest imitators of Menander. Cæcilius stole from him many of the titles, and probably a great part of the substance, of his plays. Afranius is accused by Horace, in the language of allegory, of wearing a gown that once fitted Menander. So openly and extensively did Terence plagiarize from the famous Greek comic poet, that Cæsar addresses him as "Dimidiate

Menander." The following eulogy of Menander is given by Quinctilian (x. l.):—"He has delineated the picture of human life most accurately; his invention is fruitful, his eloquence powerful, his characters, passions, and manners proper and natural."

Menander was handsome in person, polished in his manners, and self-possessed in his bearing. His scrupulous attention to elegance and effect transformed him sometimes into a coxcomb. He was wont to come into his patron's presence with a mincing gait and languid air, redolent of perfumes, and clad in a nicely adjusted robe; yet the native good-humour of his countenance could not be concealed by his affectation, nor driven away by his repeated defeats at the public theatre. Meeting on one occasion his most formidable competitor, he said to him, "Pray, Philemon, do you not blush when you carry off the palm from me?" That the morality of Menander was not below that of his own age is shown by the fact that his plays were universally read, were prescribed by teachers to their pupils, and were represented at private banquets. (See the dissertation on the life of Menander affixed to Meineke's *Menandri et Philemonis Reliquiæ*, 8vo, Berlin, 1823.)

MENASSEH, Ben Israel, a celebrated rabbi, the son of a rich merchant, was born in Spain about 1604. At an early age he fled along with his father from the terrors of the Inquisition, and repaired to Holland. In his eighteenth year he succeeded his teacher Isaac Uziel as expounder of the Talmud in the synagogue at Amsterdam. His great work, *Conciliador nel Pentateucho*, Amsterdam, 1632, introduced him to the favourable notice of the learned among both Jews and Christians. In the following year a Latin translation, by Dionysius Vossius, appeared under the title of *Conciliator, sive de Convenientia Locorum S. Scripturæ quæ pugnare esse videntur.* About 1639 the seizure of his property by the Spanish Inquisition drove him to settle at Basle as a merchant. Induced soon afterwards to visit England in the hope of obtaining more privileges for his nation, Menasseh was favourably received and entertained by Cromwell. He died at Amsterdam about 1659. The rest of Menasseh's important works are,—an edition of the Hebrew Bible, without points, in 2 vols. 4to, Amsterdam, 1635; an edition of the Talmud, with notes, 8vo, Amsterdam, 1633; *De Resurrectione Mortuorum libri* iii., 8vo, Amsterdam, 1636; *De Fragilitate Humana ex Lapsu Adami, deque Divino Auxilio*, Amsterdam, 1642; *Spes Israelis*, 12mo, Amsterdam, 1650; and *A Defence of the Jews in England*, London, 1656. The *Conciliador* has been translated into English, by E. H. Lindo, in 2 vols. 8vo, London, 1842. Dr Thomas Pococke has written the Life of Menasseh in English.

MENDE, a town of France, capital of an arrondissement of the same name in the department of Lozère, is pleasantly situated on the left bank of the Lot, 75 miles N.W. of Avignon. The town, which is nearly triangular in shape, is ill built, with narrow, crooked streets. The principal buildings are the cathedral, a Gothic edifice, with two spires; and the old episcopal palace, which is now the prefecture. The town has also a library and a picture gallery. In the vicinity is the hermitage of St Privat; and the surrounding country is studded with country houses. The manufacture of coarse woollen stuffs, which bear the name of the town, is extensively carried on here, and these articles are exported to Germany, Spain, and Italy. The town was fortified in 1151 by Adalbert, Bishop of Gévandan, and the ramparts now form a fine walk. This town suffered much in the civil wars of the Reformation, and was taken no less than seven times. Pop. (1851) 6345.

MENDELSSOHN, Bartholdy Felix, one of the most distinguished musicians of the nineteenth century, was born at Hamburg on the 3d of February 1809. His grandfather was the celebrated Moses Mendelssohn, a Jewish philosopher and writer on various subjects, and, among these, on the æsthetics of music. His father was a wealthy merchant of the Jewish persuasion at Berlin, who spared no expense on the literary as well as musical education of his son Felix. His mother, an accomplished woman, gave him his first lessons in music. During a visit to Paris, he and his sister received lessons on the pianoforte from Madame Bigot; and on his return to Berlin he was placed under Berger the pianist and Zelter the teacher of harmony and counterpoint. He received some lessons from Hummel; and in a few years became a first-rate pianist and an excellent organist, besides acquiring a practical knowledge of the violin, and a familiarity with the powers and uses of orchestral instruments. In 1821 he had become an excellent pianist, and had learned to improvise with great facility upon any musical theme given to him; while his retentive memory enabled him to play without book most of the finest classical pianoforte compositions. Being really in one sense an amateur musician, from the wealthy condition of his father, he was at full liberty to develop his musical powers in any form that he might choose. In that respect he was not like Handel, Haydn, Mozart, Beethoven, and others, who, as young prodigies of musical talent, had nevertheless to make their bread by their art, and to endeavour to consult the taste of the public. Probably this superiority of social condition may have influenced his feelings and the style of his musical compositions. Certainly he seems in general to have cared little for the production of that flowing and impressive melody which forms so great a charm in the works of the great composers just named, and to have devoted his attention rather to the effects of instrumentation, and to the resources of harmony, modulation, and counterpoint. In his fifteenth year he published two quartets for pianoforte, violin, viola, and violoncello. Next, a grand sonata for pianoforte and violin, and a third quartet. In 1827 he brought out at Berlin a comic opera, *Die Hochzeit des Camacho*, which did not succeed, and was withdrawn. This disappointment seems to have disgusted him for life with opera-writing. A copy of that opera, arranged for pianoforte, &c., was published at Berlin. In 1829 Mendelssohn visited London, and the writer of this article then heard him perform, at a rehearsal in the Philharmonic Society's rooms, a double concerto with Moscheles in a style that excited great admiration, and witnessed his conducting of his Overture to *A Midsummer Night's Dream*, with a minute attention to the details of orchestral effect which seemed quite new to the performers, and not a little annoying to their self-love; for Mendelssohn frequently stopped them, and made them repeat the passages over and over until he was satisfied. But the lessons that he then and afterwards gave them were not forgotten: they were laid to heart, and in a very few years rendered the London Philharmonic orchestra one of the best in Europe. From London Mendelssohn went to Edinburgh with his friend the Chevalier Neukomm, and after a short residence there, visited some of the most remarkable scenery of Scotland. His visit to Staffa suggested his Overture to *The Cave of Fingal.* He afterwards went to Paris, and performed there; and then visited Italy, where he remained about four years. After his return to Berlin he was engaged in a music-directorship at Dusseldorf, which he resigned in 1836, in consequence of irreconcilable dissensions which arose between him and the artists and amateurs. It was there that he composed and produced his Oratorio of *St Paul.* In that year he married at Frankfort. In 1837 he settled in Leipsic as director of the concerts; and the university conferred on him the title of Doctor. He was called to a court appointment at Berlin, but soon obtained leave to return to Leipsic, where he felt that he could serve his art better than at court. At Leipsic he composed most of his works; and by his unwearied exertions at last formed

Mendelssohn, Bartholdy Felix.

in that town a school of music, which is now one of the best in Europe. He was frequently called away from Leipsic to conduct performances of his own music, and several times revisited England, which, next to his own Germany, was the land he best loved. His last visit to England was in 1846, to conduct his *Elijah*, written for that year's Birmingham festival. Incessant labour at last affected his health, and rendered relaxation indispensable. He proceeded to Switzerland. In May 1846 he received news of the death of his sister, Madame Hensel, whom he tenderly loved. From this severe shock he never recovered. He endeavoured to divert his mind by making sketches of Swiss scenery,—for drawing and painting were among his many accomplishments,—but he felt that his bodily frame was decaying, and used to speak to his friends and relatives of his approaching death. Soon after his return to Leipsic he was attacked, on the 8th of October 1847, by a violent cerebral affection, which proved fatal on the 4th of November following. He left a widow and children to lament his premature death. His amiable manners, as well as his extraordinary accomplishments, endeared him to numerous friends, among whom he reckoned several in Great Britain. His domestic virtues are highly spoken of by all who knew him intimately. He was below the middle height, and delicately formed; his countenance handsome and intellectual, though somewhat effeminate. A good classical scholar, and well acquainted with modern languages, he possessed an accomplishment that is very rare among continental musicians—*i.e.*, he spoke and wrote English remarkably well. Though not absolutely endowed with musical genius, his musical talents were of the highest order. The dry and pedantic discipline of Zelter may have repressed the *estro* of his gifted young pupil, and such training left its impress for a long time upon the compositions of Mendelssohn. About that time also several German theoretical and æsthetical writers began to declaim against Italian melody, and to insist that in music harmony and modulation were all in all. The bad effects of this false doctrine are but too evident in the music of the new German school. Mendelssohn's early death prevented the full development of his powers of composition, for it is evident that his style was becoming year after year more free and melodious. His *St Paul*, his *Elijah*, and his Symphony in A, are proofs of this. Most of his earlier works show more of musical learning and calculation than of melodic inspiration. As he never was compelled to write for bread, he always wrote his best—always carefully and conscientiously. He was not easily satisfied with his own works. His knowledge of the art of musical composition was great; his musical reading very extensive, and his memory prodigious; his skill as a pianist and an organist almost unrivalled. Besides the works above named, Mendelssohn published the following compositions:—Overture, *Meerstille*, &c.; Overture, *Melusina;* Quintet in A for stringed instruments; two grand Quartets for stringed instruments; two Concertos for pianoforte, with orchestra; Octet for stringed instruments in E flat; three Quartets for pianoforte, violin, viola, and bass; grand Sonata for pianoforte and violin; Sonata for pianoforte and violoncello; seven characteristic pieces for pianoforte alone; Rondo for pianoforte; Sonata for pianoforte; Fantasia on an Irish air; three Fantasie for pianoforte; six melodies, without words (*Lieder ohne wörte*), for pianoforte alone; Concerto for the violin; religious Chorus, for four voices, *Aus tiefer Noth; Ave Maria*, for eight voices; religious Chorus for eight voices, *Mitten wir im Leben sind*; three Latin and German Motets, with organ accompaniment; the forty-second Psalm, with orchestra; grand Cantata for the anniversary festival of Albert Dürer; grand Cantata for the fête given by Alexander von Humboldt to the natural philosophers assembled at Berlin; three collections of songs for a single voice, with pianoforte; music to Göethe's *Walpurgis Nacht;* six Sonatas for the organ; music for *A Midsummer Night's Dream;* Choruses to *Antigone;* Symphonies for grand orchestra, in score. The above is an approximative list. Among his works that he left unpublished were,—Music to *Œdipus;* Choruses to Racine's *Athalie;* one act of his Opera of *Loreley;* songs for one voice and pianoforte, of which some of the best were written for Jenny Lind. (G. F. G.)

Mendelssohn, Moses.

Mendelssohn, *Moses*, was born in 1729 at Dessau, where his father was teacher in a Jewish school. Like all Jewish children he was from his infancy instructed in the Talmud, but the *Moreh Nevochim* ("Guide to the Wanderers") of Maimonides was the subject of his most passionate study. To the end of his days, in an impaired constitution and a distorted spine, he carried the marks of his youthful devotion to that book. In 1742 he came to Berlin, following in the footsteps of his instructor David Fränkel, and in the tide of all the aspiring Jewish youth of the day. Here, under Rabbi Israel, who had been expelled from Poland for his liberal studies, he added mathematical knowledge to the circle of his attainments; and under his teachers Emmerich, Keisch, and Solomon Gumpertz, he became acquainted with Latin and modern literature. His own philosophical genius led him to Locke, Leibnitz, and Wolf. At this time he was indebted to his countrymen Itzig, Marcus, and Bernhard for support. The last of these was a wealthy silk manufacturer, who, from being tutor to his children, ultimately raised him to partnership with himself in trade. No sooner did Mendelssohn rise above beggary than he inaugurated the grand mission of his life by aiming a blow at the bleak Talmudism of his nation. Along with Tobias Bock he prepared some short scientific tracts in Hebrew,—a step which called forth the rage and anathemas of the rabbis. In 1754 he became acquainted with Nicolai and Lessing, and began a friendship to which he owed much, and from which the critic, at least, derived profit in being furnished with the prototype of *Nathan the Wise.* From this time he devoted himself to the study of mental philosophy. His first work was the *Briefe über die Empfindungen* ("Letters on the Sensations"), and this was followed by a variety of short treatises, distinguished for acuteness more than for originality, but, above all, for the fine ethical tone which ran through them. He was engaged for many years in vindicating Lessing from the charge of Spinozism, which had been brought against him by Jacobi. His best known work, however, in this department of study is the *Phædon*, or "Dialogue of Socrates with his friends on the Immortality of the Soul." The characters and descriptive parts are taken from Plato, but the argument is new. Mendelssohn founds his doctrine, not on the simple texture of the soul, which renders it incapable of being resolved into component parts, but on its nature as exempting it from the ordinary laws of change. Kant, however, has shown that this is no argument against the soul's annihilation, and is not even satisfactory against the hypothesis of its gradual enfeeblement and ultimate decadence without any organic change. Of far greater historical importance were Mendelssohn's labours for the elevation of his Jewish countrymen. His translation of the Pentateuch into classic German, printed in Hebrew characters, introduced the literature of Germany into the Jewish schools of Poland, and ultimately extinguished the textbooks which had been conned for ages under the teaching of the Rebbe. Mendelssohn's position in the literary world was all the more startling that it was entirely novel, and whatever influence it gave him was sacredly devoted to the service of those of his own creed. His little book entitled *Jerusalem* appeared in 1783; and, along with two pamphlets written by the historian Dohm somewhat earlier, paved the way for the civil emancipation of the Jews. In these patriotic efforts he was seconded by many of his countrymen; and the work which he left unfinished was carried out by Hartwig Wesseley, Izaak Euchel, and David Friedländer. In the internal reform of the synagogue, however, he had no share. That was the second harvest of his labours, and one which, in the strictness of his own religious life, he did not anticipate.

Mendelssohn's literary labours were frequently interrupted by attacks of sickness. His constitution, shattered in early youth, received a new shock from every paroxysm of mental activity. Lavater's attempt to win him to Christianity prostrated him in a long and painful illness; and, in his zeal to defend his friend Lessing from the stigma of Spinozism, he so overtasked his energies as to bring on a fever, which terminated his existence in 1786. His works have been collected and published, along with a biography, at Vienna in 1838. A translation of the *Phædon* into English appeared in the same year.

MENDEZ PINTO, Ferdinand, was born at Montemor-o-velho in Portugal, and was at first servant to a Portuguese gentleman. In expectation of making a fortune, he embarked for India in the year 1537; but his vessel being taken by the Turks on his passage out, he was carried to Mokha, and sold to a Greek renegado, and afterwards to a Jew, in whose possession he continued till he was redeemed by the governor of Ormus, who procured him an opportunity of proceeding to India, agreeably to his original design. During a residence of twenty-one years in that country he was an eye-witness of many important transactions, and experienced many singular adventures. He returned in 1558 to Portugal, where he enjoyed the reward of his labours, after having been thirteen times a slave and sixteen times sold. A very curious account of his travels was written by himself, and published in Lisbon in 1614, folio. This work was translated into French by Bernard Figuier, a Portuguese gentleman, and printed at Paris in 1654, 4to. It is written in a very interesting manner, and in a style more elegant than might have been expected from a man whose whole life had been spent in the camp and in slavery. It relates with much credulity a great variety of particulars relating to the geography, history, and manners of the inhabitants of China, Japan, Pegu, Siam, Achem, Java, and other countries.

MENDICANTS, or Begging Friars, a religious order, appear in ecclesiastical history in the thirteenth century, at a time when the older castes of monks had lapsed into luxury and indolence, and were neglecting the instruction of the people. The men selected for this new society were well versed in the truths of the gospel, and were full of piety and holy zeal. Utterly destitute of all fixed revenues and possessions, they were forced to face every kind of hardship and self-denial. They were found in every country, under every variety of climate, travelling from village to village on their mission of love, suffering the ridicule of the scoffer and the persecution of the jealous ecclesiastic, toiling at times in the fields to earn a shelter for the night, receiving with cheerfulness the smallest crust that poverty could spare, and preaching continually, both by their lives and by their words, the healing truths of the gospel. In no long time their self-denying humanity and spotless character recommended religion to all classes of the laity, and requickened the dying influence of the church. Accordingly, Innocent III. thought it his duty to increase the respectability and usefulness of the Mendicants by releasing them from the jurisdiction of the bishops, and by rendering them responsible to the Roman see alone. The example of this pope was followed by several of his successors, and in consequence of this high patronage the number of the Mendicants continued to increase greatly. Of their many orders, the Franciscans and Dominicans speedily usurped all the zeal and influence of the others. Admitted, as confessors, into the confidence of all classes, they gradually stripped the clergy of all power and repute. At the same time their own reputation for zeal and piety procured their admission to the pulpits of pious bishops, and to the chairs of several universities. Young men of talent, brought up at their feet, were fascinated by their learning and eloquence, and caught their apostolic zeal. Their influence, therefore, spread rapidly through every country, until all Europe was filled with admiration and esteem for the Mendicants. In course of time they found their way into the highest civil offices, into the cabinets of kings, and the courts of popes. Becoming intoxicated with prosperity, they began to grow worldly-minded, to lend themselves as tools for papal extortion and ambition, to be puffed up with arrogance, to build spacious mansions, and to fare luxuriously. They even presumed to declare that they were the only real ministers of the gospel, that their indulgences were superior in efficacy to all others, and that they had supernatural intercourse with the saints, the Virgin Mary, and the Supreme Being. For some time a spirit of hatred against the Mendicants had become universally prevalent among the clergy, and it now broke forth into open hostility. Foremost among the assailants, William of St Amour, a doctor of the Sorbonne, attacked them in 1255 in a book entitled *The Perils of the Latter Times*. Several replies were written by Bonaventura, Thomas Aquinas, and other Mendicants; and in 1256 the controversy was stopped for the time by the decree of Pope Alexander IV., that William of St Amour should be banished, and that his book should be burned. The first check that the society experienced happened in 1272, when Gregory X., in a general council at Lyons, reduced their many orders to four, namely, the Dominicans, Franciscans, Carmelites, and Augustinians. Yet their influence did not decrease along with their number. Many cities about this time were divided into four parts, to afford distinctive spheres for the four sections of the Begging Friars. To receive the sacraments from a Mendicant priest, and to be buried in a Mendicant church, were the earnest wishes of every one. In the fourteenth century it was a common custom for those tottering on the brink of the grave to enter the ranks of this order, in the sure conviction that they were thus securing their salvation. Many on their deathbeds were comforted by the thought that the tattered Franciscan or Dominican garment in which they had ordered their dead limbs to be wound would save their souls at the last day. The Mendicants, however, during this century met with the most determined opposition from the clergy in all countries, and more especially from John de Polliac in France and John Wickliffe in England. This hostility continued until it was completely merged in the greater struggle of the Reformation. In the sixteenth century the position and influence of the Mendicants were usurped by the newly-instituted Society of Jesus.

MENDIP HILLS, a range of hills in England, county of Somerset, extending through the centre of the county from W. by N. to E. by S., having a length of about 25 miles, with an average breadth of 4 or 5, and rising in some places to the height of 1000 feet. The central ridge of these hills consists of old red sandstone, on the sloping sides of which strata of mountain limestone recline at various angles. These strata in several places entirely cover the sandstone, which is prominent in the most elevated parts of the range, forming four distinct ridges nearly equally distant from one another. The most remarkable features in the Mendip Hills are, a cavern called Woolsey Hole, and the Cheddar Cliffs, a long range of perpendicular crags overhanging a defile in the hills. The mineral productions are of considerable importance, consisting of lead, zinc, calamine, and coal. Part of the ground is cultivated, but the greater portion is used as pasturage for sheep.

MENDOZA, Diego Hurtado de, an eminent scholar, Mendoza, Diego Hurtado de.

statesman, and general of Spain, and grandson of the elegant Santillana, was born at Granada in 1503, of a family which, after the blood-royal, was perhaps the most illustrious in the kingdom. Lope de Vega turns aside in his *Arauco Domado* to boast that the name of the Mendozas had been nobly great for three-and-twenty generations. As Diego had five brothers older than himself, he was originally destined for the church; and after receiving his elementary education at home, he proceeded to Salamanca, where he studied Latin, Greek, philosophy, and canon and civil law. But Mendoza early showed a decided predilection for politics and elegant literature, and resolved accordingly to abandon the idea of becoming a churchman. During his residence at the university he produced his *Lazarillo de Tórmes*, a work of real genius, which appeared in 1553, and which has been a favourite in most modern languages down to the present day. It is a sort of comic romance, written in that *gusto picaresco*, or style of the rogues, so peculiar to Spain, and which, since the time of Mendoza, in the *Gil Blas* of Le Sage, and other works, has become famous throughout the world. Its object is to satirize all classes of society by assuming the character of a dexterous rogue, who, in his capacity of servant, gets behind the scenes and sees the actors in undress. It is written in a rich, bold, racy, Castilian style; and some of its sketches for freshness and spirit are unsurpassed in the whole range of prose works of fiction. The light, jovial, flexible audacity of the hero rendered him a great favourite with the grave Castilians. It nevertheless proved too much for the clergy, who issued an order for its expurgation, and solemnly denounced the anonymous author. Several continuations of the *Lazarillo de Tórmes*, by different writers, appeared afterwards, but none of them possessed much merit. Leaving the university, Mendoza joined the great Spanish armies in Italy; and while he entered with enthusiasm upon the duties of his new profession, he nevertheless found occasion, when the troops were unoccupied, to indulge his strong literary sympathies by listening to the lectures of the celebrated professors of Bologna, Padua, and Rome. The keen insight of Charles V. soon detected qualities in the young Spaniard which he resolved to turn to good account. Accordingly, in 1538 he appointed him his ambassador to Venice, afterwards made him military governor of Siena, and at a somewhat later date employed him to sustain the imperial interests at the famous Council of Trent. In 1547, while the council still sat, he was despatched by his royal master as a special plenipotentiary to Rome, to bring Pope Julius III. to a proper understanding. He boldly confronted and overawed his holiness in his own capital, and after rebuking him in open council, established himself in Italy, and governed that country for six years with great talent and firmness. But Charles, eager to conciliate the European powers before his abdication, began to alter his policy; and Mendoza, anxious for rest from his trying labours, returned to Spain in 1554 with a reputation for skill as an ambassador which afterwards passed into a proverb. The policy of Philip II. and the temper of Mendoza were little suited to one another, and the harsh tyranny of the emperor soon found means of ridding himself of the trusty ambassador. Having engaged in a passionate dispute with a courtier in the palace, the latter drew his dagger upon Mendoza, when the old warrior, who had lost little of the fire of his youth, though sixty-four years of age, wrested the weapon from the hands of his assailant, and flung it out of the balcony, throwing, as some add, the courtier after it. The spirited veteran could not be pardoned for such an affront to the royal dignity, and with his honours and gray hairs thick upon him, he was exiled from the court. The man, however, who in his college days had written *Lazarillo*, and who during the busiest negotiations had always found time to cultivate letters, was not likely to lament very deeply his apparent disgrace, if it brought him into closer intimacy with his old travelling companions, the *Amadis* and the *Celestina*. He accordingly found solace during his exile in writing poetry, collecting manuscripts, and in composing his *Guerra contra los Moriscos*, or "War against the Moors" (1568-1570). From Mendoza's long residence in Venice and Rome, and from his early and close intimacy with Boscan, he could hardly have escaped from the influence of the Italian school of poetry. Yet his verses, both in spirit and in form, are often characterized by a strong Spanish element; and while the reader meets obvious traces of his careful study of Horace and Pindar in his "Epistle to Boscan" and in his "Hymn to Espinosa," those beautiful productions are nevertheless full of the genuine old Castilian spirit. Some of his *letrillas* have a charming gaiety about them, and a light and idle humour, which savours much more of the author of *Lazarillo* than of the dignified ambassador. His history is written with great power and energy, in a style closely modelled after Sallust and Tacitus, displaying by turns more exuberance than the one, and nearly all the severity of the other This work is characterized by great impartiality,—not sparing even the author's own immediate relations who played an important part in these Moorish wars, and doing the hated enemies of his country so much generous justice that the book could not be published until 1610. Altogether it is perhaps the finest specimen of historical writing in the Spanish language. It was Mendoza's last work. In 1575 he obtained permission to return to Madrid, but died shortly after his arrival, at the advanced age of seventy-two.

Previous to his death Mendoza bequeathed the valuable classics and manuscripts he had collected with so much trouble in Italy, Greece, and Granada, to the Royal Library of the Escurial. The first complete edition of the *Guerra de Granada* is that of Montfort, with a Life of the author, Valencia, 1776, 4to. The only edition of his poems is that of Juan Diaz, Madrid, 1610, 4to. (See Life of Mendoza by N. Antonio in the *Bibliotheca Nova;* also Ticknor's *Hist. of Spanish Lit.*, vol. i., 1849.)

Mendoza, Inigo Lopez de.

Mendoza, *Iñigo Lopez de*, commonly known as the *Marques de Santillana*, the most elegant scholar and poet of the brilliant court of Juan II. of Spain, was born in 1398 of a highly distinguished family, which has sometimes claimed its origin from the Cid himself. His father, the Grand Admiral of Castile, having died while Iñigo was yet young, the family possessions, then the largest in the kingdom, were almost entirely wrested from the young heir by those bold and rapacious barons who then divided among themselves the resources as well as the power of the crown. But it did not accord with the temper of a Mendoza to submit to such wrong. As early as the age of eighteen we find that, partly by law and partly by force of arms, the young nobleman had succeeded in recovering his estates; and, as Oviedo quaintly informs us, "so began forthwith to be accounted much of a man." From this period we find him acting an important part in the stirring and wild times from which the reign of even the polished Juan II. was not free. If he suffered a defeat from the Navarrese, he gained enduring glory by his personal bravery and military skill; and attained to the rank of a marquis after the battle of Olmedo in 1445. While Santillana was frequently compelled to oppose the policy and conduct of the royal favourite, the constable Alvaro de Luna, he seems to have had but little share in the last scenes of the singular tragedy which found its catastrophe in the sacrifice of that able minister. From the fall of the constable till the death of Santillana in 1485, the marquis spent the greater part of his time in literary retirement.

During the confusion and violence of a turbulent age, the active part which he was called upon to take in state affairs never for a moment destroyed Santillana's earnest attachment to elegant literature. He remarked to Prince Henry, that "knowledge neither blunts the point of the lance nor weakens the arm that wields a knightly sword." His poetical works reflect distinctly the several influences of education and literary intercourse peculiar to his position and time. His works connect themselves more or less with the Provençal, Italian, and Spanish schools. The most graceful of all his poems is entirely in the Provençal manner, and yet for beauty and sweetness it has never been surpassed either in the Provençal or in the Spanish. It is called *Una Serranilla* (a little mountain song), and was composed on a little girl whom he found, when pursuing his military life, tending her father's flocks on the hills; and "the charming milk-maiden of sweet Finojosa" has borne some portion of her charms, even through the clumsy medium of translations, to many readers far beyond her native hills. The Marques has likewise the reputation of being the first to introduce the Italian sonnet into Spain; and which, since the time of Boscan, has gained for itself such a prominent place in the poetry of that country. The sonnets of Santillana possess little merit, however, except that of smooth and graceful versification. In his poem on the death of the Marques of Villena he imitates the opening of the *Inferno;* and his piece on the coronation of Jordi reminds the reader not unfrequently of the *Purgatorio* of the great Italian. His principal works, however, were chiefly in the manner then popular at the Spanish court; and many of them are so filled with conceits and affectation as to be almost destitute of value. Yet occasional passages are to be found in his *Ages of the World*, and *Fall and Death of the Constable*, which for strength, fluency, and grace, are worthy of the highest praise. But the most important, if not the most popular, of the poetical works of Santillana is the *Comedieta de Ponza*, founded on a great naval engagement near the island of Ponza in 1435, and approaching in its structure the form of a drama. It is, however, a sort of dream or vision, and as the poem was written shortly after the occurrence of the national calamity at Ponza, the principal figures are those of his own time. It is written in the old Italian octave stanza, in easy verse, prankt full of all manner of ancient learning, awkwardly introduced, and frequently displaying very bad taste. The most popular of all this nobleman's works is his collection of proverbs, made at the request of Juan II. for the instruction of Prince Henri. It is made up of a hundred sentences in rhyme of no poetical value, each containing one proverb. The Marques made another collection of unrhymed proverbs, gathered, as he phrases it, "from the lips of the old women in their chimney-corners." In these "short sentences drawn from long experience," as Cervantes calls them, Spain is in advance of all other countries. One of the most important documents we possess respecting the earlier Spanish literature is from the pen of this nobleman, and consists of a letter on the poetic art, written about 1455, and addressed to the young Constable of Portugal, who had asked the Marques for a copy of his poems.

The leading facts in the life of this remarkable man are to be gathered from the Chronicle of Juan II.; but a very excellent sketch of him is to be found in Pulgar's *Claros Varones*, c. iv.; and a clumsy but elaborate biography in Sanchez, *Poesias Anteriores*, vol. i. (Ticknor's *Hist. of Spanish Lit.*, vol. i., 1849).

MENDOZA, a province, town, and river of the Argentine Confederacy, South America. The province is bounded on the N. by that of San Juan, E. by San Luis, S. by an unsettled and desert region, and W. by Chili; and is about 150 miles in length, and nearly the same in breadth. The country for the most part is flat, except towards the W., where the Paramillo range of the Andes and some other branches diversify the form of the surface. In this part of the province are found several volcanoes. The principal rivers are the Mendoza, the Desaguadero, and the Tunuyan; and there are several lakes. The soil is for the most part sandy and sterile, but when well watered it is by no means unproductive. Corn, fruits, olives, and wine are the chief articles produced; and these, along with hides, soap, and tallow, constitute the most part of the export trade. Silver and copper are found here, as well as limestone, alum, slates, &c. Mendoza is an independent state, owing little subjection to the central government of the confederacy. The governor, who has the chief executive authority, is elected by the Junta or provincial assembly. The capital is Mendoza, situated at the foot of the Andes; Lat. 32. 53. S., Long. 69. 6. W. The city is neatly built and pleasantly situated; and from its dry, healthy climate, has obtained the name of the Montpellier of South America. The houses are for the most part low, and have gardens or orchards round them. Among its buildings are a handsome church and several convents. The public promenade, called the Alameda, which is about a mile long, under a fine avenue of poplars, is one of the best in South America. Pop. of the town, 12,000; of the province, 57,000.

The River Mendoza rises in the above province, near the volcano of Aconcagua; flows S.E. till about 10 miles from the town Mendoza, then turns to the N., and after a total course of 200 miles, falls into Lake Guanacache.

MENDRISO, a town of Switzerland, the capital of a district of the same name, in the canton of Tesino. It contains 1550 inhabitants, who are active and intelligent, and carry on much silk spinning. Being on the southern declivity of the Alps, the climate and productions resemble more those of Italy than the rest of Switzerland. It is only three miles from Lugarno, and nine from the lake of Como; and the vicinity yields excellent wheat, wine, tobacco, and silk. It consists chiefly of one long street, with a collegiate church, a Capuchin convent, and a nunnery of Ursulines.

MENEDEMUS, a Greek philosopher, was the son of Cleisthenes, a man of poor means, but of noble birth, and was born about 300 B.C. at Eretria, the capital of Eubœa. According to his biographer Diogenes Laertius, he was trained by his father to the trade of building and tent-making. But Athenæus represents him in his younger years as a miller, grinding in the mill all night, and studying philosophy during the day. A military appointment which he received at Megara gave him an opportunity of prosecuting his favourite study under Stilpo. He then repaired to Elis, and became a disciple of the Elean school of philosophy, which had recently been founded by Phædo. On his return to Eretria, Menedemus became a teacher of the doctrines he had learned at Elis. His character probably prevented an immediate rise in his new vocation, but was no doubt the means of his ultimate success. He was grave and taciturn, satirical, and disposed to rebuke every misdemeanour by a stinging sarcasm; fiery in temper, and declaiming frequently till be became black in the face. As he was indistinct in his elocution, we may infer that he was not very fascinating in his prelections. Yet his open and sterling disposition, and the satisfactory nature of his instructions, raised him to so great an eminence that the doctrines which he taught became identified with his school, and the Elean philosophy came to be called the Eretrian. In the same slow and sure manner did he rise to the highest civil offices. While Menedemus was thus acquiring fame and riches he was living in the same house with Asclepiades, the long-tried friend who had been his companion in his early hardships, and who was now admitted to be his companion in his good fortune. The avowed favour of Menedemus for Antigonus Gonatas led him to be suspected of a design to betray Eretria into that monarch's power. With the intention of vindicating his patriotism, he repaired to Antigonus, and besought him to restore his country to freedom; but meeting with a refusal, he starved himself to death, at the age of seventy-four.

As Menedemus did not commit his opinions to writing, the distinctive principles of the Eretrian school have been very partially and very vaguely ascertained. From Diogenes Laertius, however, we know that they resembled the school of Megara in the extreme and frivolous subtlety of their dialectics. Adopting also the Megaric doctrine, that existence was of necessity *simple*, and was therefore knowable only by direct cognition, they rejected all negative and hypothetical propositions. The same extreme generalization they employed in evolving a system of ethics. After taking an articulate distinction between the *good* and the *useful*, they proceeded to prove that all the virtues, though considered by ordinary thinking to be distinct from each other, are merely different forms of one idea, and are therefore essentially identical. They concluded their ethical system with asserting the complete identity of the *good* and the *true*.

MENEHOULD, Sainte, a town of France, capital of an arrondissement of the same name, in the department of Marne, is situated between two rocks on the Aisne, 26 miles E.N.E. of Châlons. The town is well and regularly built, and contains two fine squares, and a town-hall with an elegant front. There is also a tribunal of primary instance and a college; and the town has several fine promenades. The manufactures consist of hosiery, leather, &c.; and in the neighbourhood are several iron, glass, and china works. There is a considerable trade in wine, corn, wood, &c. The town is ancient. It was formerly fortified, and has been besieged and taken several times;—taken in 1436 by the English, and retaken by the Constable Richemont; besieged in vain by the Protestants in 1562, and by Charles II. of Lorraine in 1592; taken in 1652 by the Spaniards, and recovered in the next year by Louis XIV. Pop. (1851) 4137.

MENELAUS, King of Lacedæmon, was the son of Atreus, and brother of Agamemnon. He appeared among the numerous princely suitors for the hand of Helen, the beautiful daughter of Jupiter and Leda, and was successful. His wife, however, was afterwards carried off by Paris, the Trojan prince, and could not be reclaimed either by threats or by negotiations. All the Greek chiefs were accordingly summoned by Menelaus and Agamemnon to avenge this insult. A fleet of sixty ships was equipped, and a formidable expedition set sail against Troy. During the ten years' siege of that city Menelaus maintained the character of a sagacious counsellor and a lion-hearted warrior. On one occasion, according to Homer, he engaged with Paris in single combat before the two armies, dragged his adversary across the plain by the helmet, and would have avenged his own wrongs with his own hand, had not Venus interfered to save her favourite. He entered Troy in the wooden horse, and during the sack and massacre that ensued he recovered Helen, and carried her off. Returning homewards, Menelaus encountered a storm that wrecked one part of his fleet on the coast of Crete, and drove the other, which contained himself, to the coast of Egypt. He then wandered about uncertainly for eight years, driven by fortune to Phœnicia, Æthiopia, and Libya, and even to Japygia in Italy, and Eryx in Sicily. At length he arrived in Myccnæ at the very time when the Argives were threatening to stone Orestes and Electra for the murder of their mother Clytæmnestra. On the apotheosis of Castor and Pollux, the kingdom of Laconia was surrendered to Menelaus by his reputed father-in-law Tyndareus. It is related by Homer, that when Telemachus, wandering about in search of his father, arrived at Sparta, he found Menelaus and Helen enthroned in great magnificence in a lofty palace that blazed in splendour like the sun or moon. They were celebrating, amid a crowd of princely guests, the marriage of their son Megapenthes to a daughter of Alector, and of their daughter Hermione to Neoptolemus. On account of his relationship to Jove, Menelaus, according to Homer, was fated to be transported, along with his wife, to the Elysian Fields without ever tasting death. Their tomb, however, was wont to be shown at Therapne, not far from Sparta. (Hom. *Il.* and *Od.*)

MENES. See Egypt.

MENGS, Antony Raphael, a distinguished painter, was the son of a Danish artist of no high standing, and was born at Aussig in Bohemia on the 12th March 1728. From his sixth year he was forced by his father, on pain of severe chastisement, to study drawing for sixteen hours every day during both summer and winter. After receiving instructions in miniature and enamel painting, he was carried by his parent to Rome in 1741. On his arrival at Dresden in 1746 Mengs was appointed court painter to King Augustus. A second visit was paid to Rome in the subsequent year, for the purpose of renewing his studies and gaining a knowledge of anatomy. It was there in 1748 that his genius was first fully displayed in a picture of the "Holy Family." The model for the Virgin was a beautiful peasant girl, who in the same year became his wife, and induced him to embrace the Catholic religion. Returning to Dresden soon afterwards, he was appointed principal court-painter, and was presented by the king with a pension of 1000 dollars. A commission from the king to execute an altar-piece for the new chapel at Dresden rendered it necessary that he should return to Italy with his family in 1752. Simultaneously with the work just mentioned Mengs painted a copy of Raphael's "School of Athens" for Lord Percy, afterwards Duke of Northumberland. The outbreak of the Seven Years' War stopped the payment of his pension, and prevented his return to Saxony. This misfortune, however, was compensated by his appointment in 1754 to the professorship in the new academy of painting in the Capitol. Invited about this time to Naples, he executed the portraits of the Neapolitan royal family. On his return to Rome in 1757 he began his first attempt in fresco, the ceiling of the church of St Eusebio. His masterpiece, however, was the beautiful ceiling in the Villa Albani, representing "Apollo and the Nine Muses on Mount Parnassus." In 1761 Mengs, at the request of Charles III. of Spain, proceeded to Madrid, and was employed there for several years in executing an oil-painting of "The Passion," for the bed-chamber of the king, and some frescoes representing the "Birth of Aurora," the "Apotheosis of Hercules," and the "Apotheosis of Trajan." His declining health, however, rendered a change of climate necessary, and in 1769 he returned to Italy. After a sojourn of three years, occupied chiefly in the painting of the ceiling of the Camera de' Papiri at Rome, he repaired once more to Spain. But in 1775, when his constitution was almost prostrated under the uncongenial climate, he bade a final farewell to that country. On his arrival in Rome his sickness gradually left him, only to be brought back with overwhelming force by the death of his amiable wife in 1778. He died on the 29th June 1779. His friend, the Cavalier d'Azara, erected a monument to him, and obtained from the King of Spain pensions for his two sons and five daughters.

The character of his pictures is rather correct in design than vigorous, and his tone of colouring is deficient in brilliancy. His writings, edited in Italian by Azara in 1780, contain many excellent observations both on the practice and theory of his art. Among the various translations into the principal modern languages is one into English in 2 vols. 8vo, London, 1796.

MENG-TSEU, whose name has been Latinized into *Mencius*, the most eminent Chinese philosopher after Confucius, flourished during the first half of the fourth century b.c., and thus belonged to the same epoch with Socrates, Plato, and Aristotle. He was born in Tséou, a town in the province of Chan-toung, where his tomb is still shown. He lost his father, Meng-Kho, a short time after his birth, and his early education was left entirely in the hands of his mother, a woman still held in high veneration by the Chinese for the singular care and enlightenment which she displayed in the training of her fatherless boy. Persuaded that a bad example exercised a pernicious influence over the mind of the lad, she repeatedly changed her place of abode to remove him from temptation. She had the good fortune ultimately to settle down in the vicinity of a public school, which at once had the effect of stimulating his desire for knowledge. He became the disciple of Tseu-sse, the worthy descendant and representative of Confucius, under whom he made rapid advancement in the knowledge of the doctrines of that illustrious philosopher. Meng-Tseu soon found himself at the head of a group of ardent disciples, with whom he wandered about, a sort of Chinese Peripatetic, visiting, as the custom was, the different states of the empire at once to learn and to teach. Living in an epoch and in a country in which politics formed an integral part of morals, Meng-Tseu, both from the peculiar turn of his mind, and from his principles, felt disinclined to separate them. Accordingly, in his work, the *Meng*, which bears his name, he preserves a strict union between those two sciences. His politics appear to have displayed more decision and boldness than those of his master Confucius, for whom he constantly professed the highest admiration. While Meng-Tseu never ceases to inculcate the duty of political obedience, he nevertheless opposes strongly the law of justice to the tyrannous will of power. If he was less solid, he had a keener faculty than Confucius, and he assailed his adversary, whether prince or otherwise, with the most ruthless Socratic pertinacity, pursuing him from premise to conclusion, until he had him entangled in a network of absurdities. In his method and spirit he closely resembles his great Greek contemporary, the terror of the sophists; and there is perhaps no oriental philosopher who presents greater attractions to a European reader. He considered philosophy the great regenerator of the human race; and his work is one of the four classics which form the basis of instruction in all the public and private schools of China. The most eminent of her philosophers have expounded and commented on him, and his works are in the hands of all those who wish to attain to a knowledge of those eternal truths which form the most solid basis of human society. He died about the year 314 B.C. at the age of eighty-four.

Of Meng-Tseu's work, which has been frequently translated into different European languages, there is a Latin version by Stanislaus Julien, entitled *Meng-Tseu, vel Mencium inter Sinenses Philosophos ingenio, doctrina, &c., Confucio proximum edidit*, &c., 8vo., Paris, 1824–1829. There is also a French version by G. Pauthier in the *Livres Sacrés de l'Orient*, Paris, 1840; and in the volume of the Bibliothèque Charpentier, entitled *Confucius et Mencius, ou les Quatre Livres de Philosophie Morale et Politique de la Chine*, Paris, 1841; and there is an English translation of the *Four Books*, executed by the Rev. Mr Collie, and published at Malacca in 1828. (See *Dictionnaire des Sciences Philosophiques.*)

MENIN (Flemish *Meenen*), a town of Belgium, province of West Flanders, on the left bank of the Lys, 30 miles S. of Bruges, and 7 W.S.W. of Courtray. It is regularly built and strongly fortified, but has a dull and gloomy appearance. The principal building is the church; and there are also a college and several schools. The manufactures consist of linen, lace, soap, oil, tobacco, woollen stuffs, chocolate, and candles; and the town has also breweries, tanneries, dyeworks, and bleachfields. The trade consists in agricultural produce, horses, cattle, &c. Pop. 8268.

MENIPPUS, a Cynic philosopher, with whose private history we are but very slightly acquainted. It is supposed that he was a native of Gadara, a small village of Phœnicia (Strab. xvi. 759), and that he lived before the year 200 B.C., as he is spoken of by Hermippus, according to Diogenes Laërtius. He was originally a slave, but having purchased his liberty, he settled at Thebes, where he obtained the rights and privileges of a citizen. Lucian, in his *Dialogues of the Dead*, makes Diogenes describe him as "old, bald-headed, wearing a threadbare cloak, with abundance of apertures in it, pervious to every wind, and patched with rags of all possible colours; and as laughing incessantly at those conceited pedants the philosophers, who are generally the objects of his derision." Varro in his *Satires* imitated the style of Menippus, so that they were called *Satiræ Menippeæ*. (Cic. 1, 2; Gell. xi. 18., xiii. 30.)

MENNO, surnamed SIMONIS, the founder of the sect of the *Mennonites*, was born in 1505 at Witmarsum, a village near Bolswert in Friesland. At first he was a Roman Catholic priest, and was remarkable for nothing but gross sensuality. He then became a secret convert to the opinions of the Anabaptists, and in 1536 openly joined that body. With a change of opinions a change of morals had been simultaneous. He was now meek and gentle in disposition, kind and courteous to all men, blameless in his conduct, and full of apostolic zeal. With these qualities, a real though undisciplined genius, a rough and forcible eloquence, and a considerable amount of learning, combined to raise him to a high position in the sect which he had recently joined. He was accordingly requested in a short time to assume the functions of a public teacher. In this capacity he travelled with his wife and children through East and West Friesland, Gröningen, Holland, Guelderland, Brabant, Westphalia, and the German provinces on the coast of the Baltic. By rejecting most of the extreme tenets of the Anabaptists he attracted towards his ministrations the judicious and liberal-minded of that sect, and thus became the acknowledged head of a new body of separatists. As yet, however, the civil authorities recognised no distinction between his followers and the radical Anabaptists. Some of the Mennonites suffered martyrdom, and others, including their leader, escaped the same fate only by being received into the mansion of a kind-hearted nobleman in the duchy of Holstein. There they found a safe asylum from persecution, and there Menno Simonis died in 1561.

The *Mennonites* receive the old Anabaptist creed in a form modified and considerably altered. The dogmas regarding the millennium, the exclusion of magistrates from the church, the abolition of war, the sinfulness of taking oaths, and the vanity of human science, have lost much of the harshness of their original features, and appear in an aspect more conformable both to reason and revelation. At the same time, the distinctive doctrine of the Anabaptists, which declares that converts from other Christian churches ought to be rebaptized, is repudiated. The blind fanaticism that impelled the disciples of Anabaptism at the beginning of the sixteenth century to believe in the divine appointment of polygamy, to hold up the liberal arts to scorn and hatred, to encourage the assassination of impious magistrates, and to attempt to establish the kingdom of Sion in the city of Munster, is likewise utterly disowned. Indeed, so far have the Mennonites separated from the Anabaptists, that the former disclaim all connection with the latter, and believe that they have derived their origin and opinions from the ancient Waldenses. (See ANABAPTISTS.) The Mennonites are subdivided into several sects, slightly differing from each other. Of these the principal two are the *Flandrians* or *Flemingians*, and the *Waterlandians*. (Schyn's *Mennonitarum Historiæ*, and Mosheim's *Ecclesiastical History*.)

MENSURATION.

1. Mensuration, or the art of measuring, involves the construction of measures, the methods of using them, and the investigation of rules by which magnitudes, which it may be difficult or impossible to measure directly, are calculated from the ascertained value of some associated magnitude. It is usual, however, to employ the term mensuration in the last of these senses; and we may therefore define it to be that department of mathematical science by which the various dimensions of bodies are calculated from the simplest possible measurements.

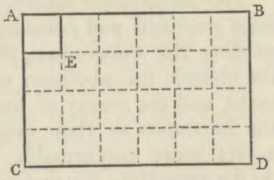
The determination of the lengths and directions of straight lines, including what are familiarly known as problems in heights and distances, generally depends on the solution of triangles, and will be discussed in the articles Trigonometry and Surveying. The remaining portions of the subject, which will form the subject of the present article, are the determinations of the lengths of curves, the areas of plane or other figures, and the volumes and surfaces of solids. Even thus restricted, the science of mensuration is obviously of very great extent, and our space will only permit us to discuss some of its more interesting and important problems.

The reader will find tables of the numbers most frequently required in mensuration at the end of this article, and a complete account of measures in the article Weights and Measures.

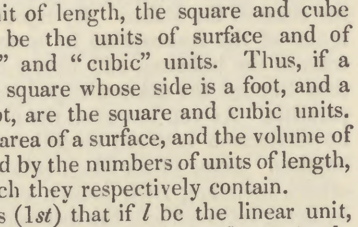
2. *On the Numerical Expression of the Length of a Line, the Area of a Surface, and the Volume of a Solid.*—If any line be chosen as the unit of length, the square and cube described upon it will be the units of surface and of volume, or the "square" and "cubic" units. Thus, if a foot be the linear unit, a square whose side is a foot, and a cube whose edge is a foot, are the square and cubic units. The length of a line, the area of a surface, and the volume of a solid, are then expressed by the numbers of units of length, surface, and volume which they respectively contain.

3. From this it follows (1*st*) that if l be the linear unit, the length of a line which contains a units is al; or simply a, for l is reckoned as unity.

4. (2*d*) If the length and breadth of a rectangle AD be divided into linear units, and lines be drawn through the points of section, parallel to its sides, it is evident that the rectangle will be divided into as many square units AE, as there are linear units in its length AB, repeated as often as there are linear units in its breadth AC; or the number of square units contained by the figure will be obtained by multiplying its length by its breadth. Hence if the length AB contain a, and the breadth AC contain b units, the surface AD will contain ab square units.



5. (3*d*) If the length, breadth, and height of a parallelopiped BCD be divided into linear units by planes drawn parallel to its faces, it will obviously be divided into cubic units such as EF; and if AB, AC, AD contain a, b, and c units respectively, it appears from the diagram that the portion of the solid between the face BC, and the plane passing through EG, EH, contains ab cubic units. Similarly, each of the sections of the solid between two contiguous planes passing through the divisions of AD, contains ab cubic units; and since AD is divided into c parts, the whole solid contains abc units of volume.



The demonstrations of the preceding propositions might be extended to include the cases where the linear dimensions are fractional, or incommensurable with the linear unit.

SECTION I.—PLANE FIGURES CONTAINED BY STRAIGHT LINES.

6. *To find the Area of a Rectangle.*—It has been proved in article 4, that if a and b be the sides of a rectangle,

$$\text{the area} = ab;$$

or the area of a rectangle is equal to its length multiplied by its breadth.

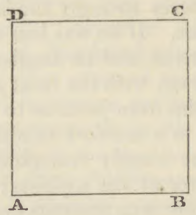
Whence, also, if a be the side of a square,

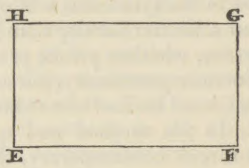
$$\text{the area of the square} = a^2.$$

Example 1.—Find the area of a square BD, whose side is 15 chains 40 links.

Here the side of the square = 1540 links; therefore

$$\text{the area} = (1540)^2 = 2371600 \text{ square links}$$
$$= 23 \text{ a. } 2 \text{ r. } 34{\cdot}56 \text{ p.}$$





Example 2.—Find the area of a rectangle EG, whose sides are 12 feet 6 inches and 9 inches.

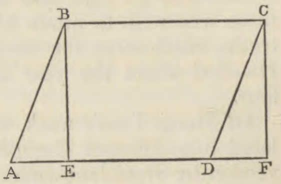
$$\text{The area} = 12{\cdot}5 \times {\cdot}75 = 9{\cdot}375 \text{ square feet.}$$

7. *To find the Area of a Parallelogram.*—(i.) *The area in terms of the base and perpendicular breadth.*

The parallelogram ABCD is equal to the rectangle BEFC (Geom., sec. iv., theor. 1; or, *Euc.* i., 35). Wherefore the area ABCD = BC·BE = AD·BE; and putting AD = b, and BE = h,

$$\text{the area} = bh;$$

or the area of a parallelogram is equal to its length, multiplied by its perpendicular breadth.



Example.—Find the area of a parallelogram whose length is 37 and its breadth $5\frac{1}{4}$ feet.

$$\text{The area} = 37 \times 5{\cdot}25 = 194{\cdot}25 \text{ square feet.}$$

8. (ii.) *The area in terms of the sides and the included angle.*—Let AB = a, AD = b, angle BAD = A.

Then BE = a sin A; and since ABCD = BE·AD,

$$\text{the area} = ab \sin \text{A}.$$

Whence the area is obtained by multiplying together the two sides of the parallelogram and the sine of the contained angle.

Example.—The sides of a parallelogram are 36 and 25·5, and the contained angle 58°.

$$\text{The area} = 36 \times 25{\cdot}5 \times \sin 58° = 36 \times 25{\cdot}5 \times {\cdot}8480481$$
$$= 778{\cdot}50:$$

or $\log \text{area} = \log a + \log b + \text{L} \sin \text{A} - 10$*

$a = 36$ $\qquad \log a = 1·5563025$

$b = 25·5$ $\qquad \log b = 1·4065402$

$\text{A} = 58°$ $\qquad \text{L} \sin \text{A} = 9·9284205$

Area $= 778·5$ $\qquad \log \text{area} = \overline{2·8912632}$

9. (iii.) *The area in terms of the diagonals and their contained angle.*

If m, n are the diagonals, and I the contained angle, it follows, from article 17, that the

$$\text{area} = \tfrac{1}{2} mn \sin \text{I}.$$

Example.—Find the area of a parallelogram whose diagonals, are 30 and 25, which make with each other an angle of 60°.

$$\text{Area} = \tfrac{1}{2} \times 30 \times 25 \times \sin 60° = 15 \times 25 \times ·8660254$$
$$= 324·76;$$

or $\log \text{area} = \log m + \log n + \text{L} \sin \text{I} - \log. 2 - 10.$

$m = 30$ $\qquad \log m = 1·4771213$

$n = 25$ $\qquad \log n = 1·3979400$

$\text{I} = 60°$ $\qquad \text{L} \sin = 9·9375306$

$\qquad \text{colog } 2 = 9·6989700$

Area $= 324·76$ $\qquad \log \text{area} = \overline{2·5115619}$

If the parallelogram is equilateral, or a rhombus, the diagonals intersect at right angles, and $\sin \text{I} = \sin 90° = 1$.

$$\text{Whence the area} = \tfrac{1}{2} mn.$$

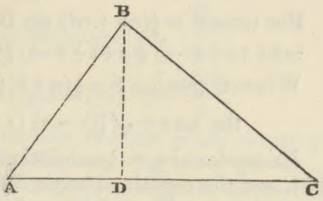
Example.—Find the area of a rhombus whose diagonals are 30 and 20 chains.

$$\text{The area} = \tfrac{1}{2} \times 30 \times 20 = 300 \text{ chains} = 30 \text{ acres}.$$

10. *To find the Area of a Triangle*—(i.) *When the base* AC, *and height* BD *are given.*—Let $\text{AC} = b$, $\text{BD} = h$. Then, since a triangle is half a rectangle of the same base and altitude (GEOM. p. 520), the area of the triangle

$$= \tfrac{1}{2} bh;$$

or the area is equal to one-half the product of one of the sides multiplied by the perpendicular let fall upon it from the opposite angle of the triangle.



Example.—A side of a triangle is 40, and the perpendicular on it from the opposite angle is 14·52 chains.

$$\text{The area} = \tfrac{1}{2} \times 40 \times 14·52 = 290·4 \text{ sq. chains}.$$
$$= 29 \text{ a. } 0 \text{ r. } 6·4 \text{ p.}$$

11. (ii.) *When two sides and the included angle are given.*—Let $\text{AC} = b$, $\text{AB} = c$.

Since $\text{ABC} = \tfrac{1}{2} \text{AC} \cdot \text{BD}$, and $\text{BD} = c \sin \text{A}$,

$$\text{the area of the triangle} = \tfrac{1}{2} bc \sin \text{A};$$

or the area is equal to one-half the continued product of the two sides, and the sine of the contained angle.

Example.—The sides of a triangle are 30 and 40, and the contained angle is 28° 57.′

$$\text{The area} = \tfrac{1}{2} \times 30 \times 40 \times \sin 28° \, 57' = 600 \times ·4840462$$
$$= 290·43;$$

or, by logarithms—

$\text{Log area} = \log b + \log c + \text{L} \sin \text{A} + \text{colog } 2 - 10$

$b = 30$ $\qquad \log \tfrac{1}{2} b = 1·1760913$

$c = 40$ $\qquad \log c = 1·6020600$

$\text{A} = 28° \, 57'$ $\qquad \text{L} \sin \text{A} = 9·6848868$

Area $= 290·43$ $\qquad \log \text{area} = \overline{2·4630381}$

12. *When the three sides of the triangle are given.*—Let $\text{BC} = a$, $\text{AC} = b$, $\text{AB} = c$; and put $\text{BD} = x$, and $\text{AD} = y$. Then $\text{CD} = b - y$;

$$\therefore c^2 = x^2 + y^2, \text{ and } a^2 = x^2 + (b - y)^2.$$

$$\text{Whence } y = \frac{b^2 + c^2 - a^2}{2b}.$$

$$\text{But } x^2 = c^2 - y^2 = c^2 - \left(\frac{b^2 + c^2 - a^2}{2b}\right)^2$$
$$= \frac{(a+b+c)\,(b+c-a)\,(a+c-b)\,(a+b-c)}{4b^2}.$$

Whence, since the square of the area of the triangle is $(\tfrac{1}{2}\text{AC} \cdot \text{DB})^2 = \tfrac{1}{4} b^2 x^2$, we have

$$(\text{area})^2 = \tfrac{1}{2}(a+b+c)\,\tfrac{1}{2}(b+c-a)\,\tfrac{1}{2}(a+c-b)\,\tfrac{1}{2}(a+b-c).$$

Now if we put $s = \tfrac{1}{2}(a+b+c)$, then $\tfrac{1}{2}(b+c-a) = s - a$, &c. Therefore substituting

$$\text{The area of the triangle} = \sqrt{\{s(s-a)\,(s-b)\,(s-c)\}}.$$

$$\text{Otherwise, since } \sin \text{A} = \frac{2}{bc} \sqrt{\{s(s-a)\,(s-b)\,(s-c)\}},$$

$$\text{the triangle} = \frac{bc}{2} \sin \text{A} = \sqrt{\{s(s-a)\,(s-b)\,(s-c)\}}.$$

Whence, to obtain the area of a triangle, from half the sum of the three sides, subtract each side separately, multiply the half sum by the three remainders successively, and extract the square root.

Example 1.—The sides of a triangle are 3, 4, and 5 feet. Find its area.

$a = 5$, $b = 4$, $c = 3$.

$s = \tfrac{1}{2}(5 + 4 + 3) = 6$; $s - a = 1$; $s - b = 2$; $s - c = 3$.

$$\text{The area} = \sqrt{6 \times 1 \times 2 \times 3} = \sqrt{36} = 6 \text{ square feet.}$$

Example 2.—The sides of a triangle are 221, 255, and 238.

$a = 255$

$b = 238$

$c = 221$

$2)\overline{714}$

$s = 357$ $\qquad \log = 2·5526682$

$s - a = 102$ $\qquad$ „ $= 2·0086002$

$s - b = 119$ $\qquad$ „ $= 2·0755470$

$s - c = 136$ $\qquad$ „ $= 2·1335389$

$\qquad 2)\overline{8·7703543}$

Area $= 24276$ $\qquad \log \text{area} = 4·3851772$

13. *When two angles and the adjacent side are given.*—Let the angles A, B and the side c be given.

$$\text{The area} = \tfrac{1}{2} bc \sin \text{A}.$$

$$\text{But } b = \frac{c \sin \text{B}}{\sin \text{C}} = \frac{c \sin \text{B}}{\sin (\text{A} + \text{B})}; \quad \because \sin \text{C} = \sin (\text{A} + \text{B}).$$

Therefore substituting,

$$\text{the area} = \frac{c^2 \sin \text{A} \sin \text{B}}{2 \sin (\text{A} + \text{B})}$$
$$= \tfrac{1}{2} c^2 \sin \text{A} \sin \text{B} \operatorname{cosec} (\text{A} + \text{B});$$

and $\log \text{area} = 2 \log c + \text{L} \sin \text{A} + \text{L} \sin \text{B} + \text{L} \operatorname{cosec} (\text{A} + \text{B}) + \text{colog } 2 - 40.$

Example.—The side of a triangle is 2405 feet, and the angles at its ends 77° 54′, and 87° 40′. Find its area in square miles.

$c = 2405$ $\qquad 2 \log c = 6·7622302$

$\text{A} = 77° \, 54'$ $\qquad \text{L} \sin \text{A} = 9·9902426$

$\text{B} = 87 \;\; 40$ $\qquad \text{L} \sin \text{B} = 9·9996398$

$\text{A} + \text{B} = 165 \;\; 34$ $\qquad \text{L} \cos (\text{A} + \text{B}) = 10·6033590$

$\qquad \text{colog } 2 = 9·6989700$

$\qquad \text{log area in ft.} = \overline{7·0544416}$

$\qquad 2 \log 5280 = 7·4452678$

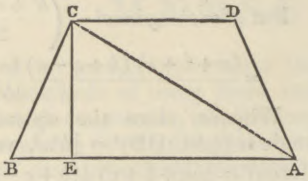
Area $= 0·40661$ sq. miles. $\qquad$ log. area in miles $= \bar{1}·6091738$

14. *To find the Area of a Trapezoid.*—Let $\text{AB} = a$, $\text{CD} = b$, $\text{CE} = h$. Then $\text{ABCD} = \text{ABC} + \text{ACD} = \tfrac{1}{2} ah + \tfrac{1}{2} bh$ (art. 10).

---

* Throughout this article we shall denote the logarithm of a number to the base 10, by $\log_{10} n$ or simply $\log n$; and the tabular logarithm of the sine, cosine, &c., of an angle A by L sin A, L cos A, &c. Since the logarithmic sines, cosines, &c., in the tables, are all increased by 10, we have $\text{L} \sin \text{A} = \log_{10} \sin \text{A} + 10$, &c. We shall also denote the arithmetical complement of $\log n$, or $10 - \log n$, by colog n.

Hence the trapezoid ABCD $= \frac{1}{2}(a+b)h$;
or the area is equal to half the sum of the parallel sides multiplied by the perpendicular breadth.

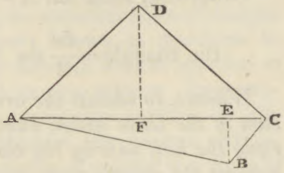


Example.—Find the area of a trapezoid whose parallel sides are 12·25 and 7·5 chains, and its breadth 15·4.

The area $= \frac{1}{2} \times (12{\cdot}25 + 7{\cdot}5) \times 15{\cdot}4 = 7{\cdot}7 \times 19{\cdot}75$
$= 152{\cdot}075$ square chains.
= 15 a. 0 r. 32·2 p.

15. *To find the Area of a Quadrilateral Figure*—(i.) *When a diagonal* AC *and perpendiculars* DF, BE *are given.*—Let AC $= a$, BE $= m$, and DF $= n$. Then ABCD = ABC + ADC $= \frac{1}{2}am + \frac{1}{2}an$ (art. 10); or,

the quadrilateral $= \frac{1}{2}a(m+n)$.



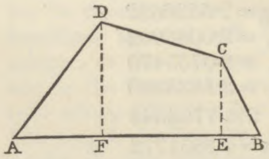
Hence the area is obtained by multiplying the diagonal by half the sum of the perpendiculars.

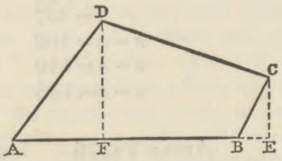
Example.—In a quadrilateral the diagonal is 42, and the perpendiculars 16 and 18.

The area $= \frac{1}{2} \times 42 \times (16+18) = 21 \times 34 = 714$.

16. (ii.) *When a side* AB *and the perpendiculars* DF, CE *are given.*

The area = ADF + CDEF + BCE.
$= \frac{1}{2}$AF·DF $+ \frac{1}{2}$(DF + CE) EF $+ \frac{1}{2}$BE·CE (arts. 10, 14)
$= \frac{1}{2}$(AE·DF + BF·CE).

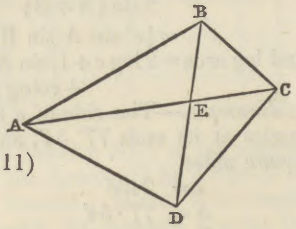




Example.—Let AB = 12, AF = 5, BE = 3, DF = 8, and CE = 6. Then AE = 12 ± 3 = 15 or 9.
BF = 12 − 5 = 7

The area $= \frac{1}{2}(9 \times 8 + 7 \times 6) = 4 \times 9 + 3 \times 7 = 57$; or,
$= \frac{1}{2}(15 \times 8 + 7 \times 6) = 4 \times 15 + 3 \times 7 = 81$.

17. (iii.) *When the diagonals and the included angle are given.*—Let AC $= m$, BD $= n$, AEB = I;
∴ BEC = 180° − AEB;
∴ Sin BEC = sin I.
ABC = ABE + BCE
$= \frac{1}{2}$AE·BE sin AEB
$+ \frac{1}{2}$CE·BE sin BEC (art. 11)
$= \frac{1}{2}$AC·BE sin AEB.



Similarly ADC $= \frac{1}{2}$AC · DE sin AEB.
Whence ABCD $= \frac{1}{2}$AC · BD sin AEB; or,

the area $= \frac{1}{2}mn$ sin I.

Therefore the area of a quadrilateral is equal to half the product of the diagonals, and the sine of their contained angle.

This rule obviously applies to parallelograms.

Example.—The diagonals of a quadrilateral are 30 and 40, and the included angle 48°.

The area $= \frac{1}{2} \times 30 \times 40 \times \sin 48°$
$= 600 \times {\cdot}7431448$
$= 435 \cdot 887$.

18. (iv.) *When the sides and the angle between the diagonals are given.*—In the figure of article 17, let AB $= a$, BC $= b$, CD $= c$, AD $= d$, BEC = I, AE $= x$, BE $= y$, EC $= z$, ED $= w$.

$$\text{Then } x^2 + y^2 + 2xy \cos \text{I} = a^2$$
$$y^2 + z^2 - 2yz \cos \text{I} = b^2$$
$$z^2 + w^2 + 2zw \cos \text{I} = c^2$$
$$w^2 + x^2 - 2wx \cos \text{I} = d^2$$

Whence $2(x+z)(y+w) \cos \text{I} = a^2 - b^2 + c^2 - d^2$.
But $2(x+z)(y+w) \cos \text{I} = \frac{1}{2}$AC·BD sin I × 4 cot I,
= area ABCD × 4 cot I (art. 17).

Therefore the area $= \frac{1}{4}(a^2 - b^2 + c^2 - d^2) \tan \text{I}$.

Example.—The sides of a quadrilateral in order are 10, 9, 8, and 7, and the angle between the diagonals is 80°. Find the area.

$$a^2 - b^2 + c^2 - d^2 = 100 - 81 + 64 - 49 = 34.$$

∴ log area = log 34 + L tan 80° + colog 4 − 10

log 34 = 1·5314789
L tan 80° = 10·7536812
colog 4 = 9·3979400
Area = 48·206. log area = 1·6831001

19. (v.) *When the quadrilateral is inscribed in a circle.*—In the figure of article 17, let AB $= a$, BC $= b$, CD $= c$, AD $= d$. Then, since the quadrilateral is inscribed in a circle, D = 180° − B;

and $a^2 + b - 2ab \cos \text{B} = \text{AC}^2 = c^2 + d^2 + 2cd \cos \text{B}$.

$$\text{From which } \cos \text{B} = \frac{a^2 + b^2 - c^2 - d^2}{2(ab + cd)}.$$

But $(\text{area})^2 = \frac{1}{4}(ab + cd) \sin \text{B}$
$= \frac{1}{2}(b+c+d-a)\,\frac{1}{2}(a+c+d-b)\,\frac{1}{2}(a+b+d-c)\,\frac{1}{2}(a+b+c-d)$.

Whence putting $\text{S} = \frac{1}{2}(a+b+c+d)$,

$$\text{the area} = \sqrt{\{(s-a)(s-b)(s-c)(s-d)\}}.$$

Example.—In a quadrilateral, two sides are 120 and 104, and the contained angle 59° 29′ 23″; and the remaining sides are 78 and 50, and the contained angle 120° 30′ 37″.

Since the sum of the opposite angles = 180°, the figure may be inscribed in a circle, and the formula applies.

$a = 120$
$b = 104$
$c = 78$
$d = 50$
352
$s = 176$
$s - a = 56$ log = 1·7481880
$s - b = 72$ " = 1·8573325
$s - c = 98$ " = 1·9912261
$s - d = 126$ " = 2·1003705
2)7·6971171
Area = 7056 log area = 3·8485586

20. (vi.) *When the four sides of the quadrilateral and a pair of opposite angles are given.*—Since the figure (art. 17) may be divided into two triangles whose areas can be found by article 11; if a, b, c, and d be the sides, we have evidently

the area $= \frac{1}{2}(ab \sin \text{B} + cd \sin \text{D})$.

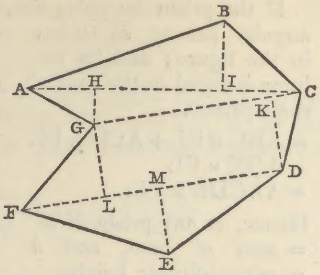
Example.—To verify the calculation of the area in the example of last article.

$a = 120$	log $a = 2{\cdot}0791812$	$c = 78$	log $c = 1{\cdot}8920946$
$b = 104$	log $b = 2{\cdot}0170333$	$d = 50$	log $d = 1{\cdot}6989700$
B = 59°29′23″	L sin B = 9·9352745	D = 120°30′37″	L sin D = 9·9352745
2ABC = 10752	4·0314890	2ADC = 3360	3·5263391

∴ 2ABCD = 14112, and ABCD = 7056.

21. *To find the Area of an Irregular Polygon.*—The figure may be divided into triangles or trapeziums;

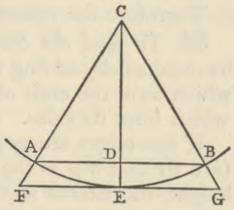
whose areas, found separately and added, will give that of the whole figure.



Example.—In the figure AD are given the diagonals AC = 5·5, CG = 4·4, FD = 5·2, and the perpendiculars BI = 1·8, GH = 1·3, DK = 2·3, GL = 1·2, EM = 0·8. Then, by articles 10 and 14,

$$\begin{aligned} 2\ \mathrm{ABCG} &= \mathrm{AC}\ (\mathrm{BI}+\mathrm{GH}) = 5{\cdot}5\ (1{\cdot}8+1{\cdot}3) = 17{\cdot}05 \\ 2\ \mathrm{DEFG} &= \mathrm{DF}\ (\mathrm{GL}+\mathrm{EM}) = 5{\cdot}2\ (1{\cdot}2+0{\cdot}8) = 10{\cdot}40 \\ 2\ \mathrm{CDG} &= \mathrm{CG}{\cdot}\mathrm{DK} = 4{\cdot}4 \times 2{\cdot}3 = 10{\cdot}12 \\ 2\ \text{area} &= 37{\cdot}57 \\ \text{area} &= 18{\cdot}785 \end{aligned}$$

22. *To find the Area of a Regular Polygon.*—If AB be one of the sides of the polygon, and C the centre of the circle described about it, the area of the polygon will be equal to that of the triangle ABC multiplied by the number of sides.



Let AB = a, and the number of sides = n. Then, since the equal sides of the polygon subtend equal angles at the centre of the circle, $\mathrm{ACB} = \frac{360^\circ}{n}$;

$$\therefore\ \mathrm{CD} = \mathrm{AD}\cot\mathrm{ACD} = \tfrac{1}{2}a\ \cot\frac{180^\circ}{n};$$

$$\text{and the triangle } \mathrm{ABC} = \mathrm{AD}{\cdot}\mathrm{DC} = \tfrac{1}{4}a^2\ \cot\frac{180}{n};$$

$$\text{whence the polygon} = \tfrac{1}{4}na^2\cot\frac{180^\circ}{n}.$$

(i.) *Hence the area of a regular polygon is one-fourth of the continued product obtained by squaring one of its sides, multiplying by the number of its sides and by the cotangent of the angle obtained by dividing* 180° *by the number of its sides.*

Example.—Find the area of a regular polygon whose side is 23 and the number of sides 15.

$$\text{Log area} = \log n + 2\log a + \mathrm{L}\cot\frac{180^\circ}{n} + \text{colog}\ 4 - 20.$$

$$\begin{array}{lrr} a = 23 & \log a = & 1{\cdot}3617272 \\ n = 15 & & 2 \\ \frac{180^\circ}{n} = 12^\circ & & \overline{2{\cdot}7234556} \\ & \log n = & 1{\cdot}1760913 \\ & \mathrm{L}\cot\frac{180^\circ}{n} = & 10{\cdot}6725255 \\ & \text{colog}\ 4 = & 9{\cdot}3979400 \\ \text{Area} = 9332{\cdot}8 & \log\text{area} = & \overline{3{\cdot}9700124} \end{array}$$

23. (ii.) If the side of the polygon = 1, its area $= \frac{n}{4}\cot\frac{180^\circ}{n}$; and the area of a polygon whose side is a, may then be obtained by multiplying by a^2. Since the number by which a^2 is to be multiplied is the *same* for all polygons of the same number of sides, it is obvious that if its values be calculated for $n=3$, $n=4$, &c., and the results collected in a table, *we shall obtain the area of any polygon by multiplying the square of its side by the appropriate tabular number.*

Table I. contains the multipliers and their logarithms for polygons of 3 to 12 sides.

Examples.—Find the areas of a regular pentagon whose side is 25, and of a hexagon whose side is 20.

The multiplier for the pentagon is 1·7204774;

$\therefore$ the pentagon = $(25)^2 \times 1{\cdot}7204774 = 1075{\cdot}298$.

To find the area of the hexagon by logarithms.

$$\begin{array}{lr} \text{The logarithm for a hexagon} = & {\cdot}4146519 \\ 2\log 20 = & \underline{2{\cdot}6020600} \\ \text{Area of hexagon} = 1039{\cdot}230 & 3{\cdot}0167119 \end{array}$$

24. *To find the Area of a Regular Polygon inscribed in a Circle.*—Let AB (fig. art. 22) be a side of the polygon; the radius AC = r, and the number of sides = n.

$$\text{Then ACD} = \frac{180^\circ}{n};$$

$$\therefore\ \mathrm{AD} = r\sin\frac{180^\circ}{n},\ \text{and CD} = r\cos\frac{180^\circ}{n};$$

and since the polygon = nABC = nAD · DC,

$$\text{its area} = nr^2\sin\frac{180^\circ}{n}\cos\frac{180^\circ}{n} = \tfrac{1}{2}nr^2\sin\frac{360^\circ}{n}.$$

Example.—The radius of a circle being 10, find the area of an inscribed hexagon.

$$\begin{aligned} \text{The area} &= \tfrac{1}{2}\times 6\times 100\sin 60^\circ = 300\times\frac{\sqrt{3}}{2} \\ &= 150\times 1{\cdot}7320508 = 259{\cdot}81. \end{aligned}$$

25. *To find the Area of a Regular Polygon described about a Circle.*—In fig. to article 22, if FG be a side of the polyglon of n sides; since FG = CE · tan ECF = r tan $\frac{180^\circ}{n}$, and the polygon = nCFG = nCE · EF;

$$\text{therefore area} = nr^2\tan\frac{180^\circ}{n}.$$

Example.—Find the area of a regular hexagon described about a circle whose radius is 10 feet.

$$\begin{aligned} \text{Area} &= 6\times 100\times\tan 30^\circ = 600\times\frac{1}{\sqrt{3}} = 200\sqrt{3} \\ &= 200\times 1{\cdot}7320508 = 346{\cdot}41. \end{aligned}$$

SECTION II.—SOLIDS CONTAINED BY PLANES.

26. *To find the Volume of a Rectangular Parallelopiped.*—If the parallelopiped be rectangular, and its edges be a, b, and c, it has been proved in article 5, that its

$$\text{volume} = abc;$$

or the volume is equal to the length multiplied by the breadth and by the height.

Example.—The volume of a parallelopiped whose length, breadth, and height are 5, 4, and 3,

$$= 5\times 4\times 3 = 60.$$

27. *To find the Surface of a Rectangular Parallelopiped.*—The surface of the parallelopiped (fig. art. 5) is evidently

$$= 2\mathrm{BC} + 2\mathrm{BD} + 2\mathrm{CD};$$

$$\therefore\ \text{surface} = 2(ab + ac + bc.)$$

Hence the surface is double the sum obtained by adding together the length multiplied by the breadth, the length multiplied by the height, and the breadth multiplied by the height.

Example.—The surface of the rectangular parallelopiped, whose length, breadth, and thickness are 5, 4, and 3,

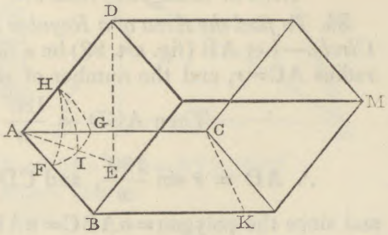
$$= 2(5\times 4 + 5\times 3 + 4\times 3) = 2(20+15+12) = 94.$$

28. *To find the Volume of any Parallelopiped*—(i.) *When the length AC of the base BC* (fig. art. 29), *its perpendicular breadth CK, and the altitude DE of the parallelopiped are given.*—It is proved (GEOM. p. 536; *Euc.* xi. 34), that a parallelopiped is equal to any other parallelopiped having an equal base and the same altitude; and as this other parallelopiped may be rectangular, its volume = base × height (art. 26). Hence the volume of the parallelopiped AM = AC·CK·DE; or if AB = l, KL = m, and DE = n,

$$\text{the volume} = lmn.$$

Example.—If the length of the base be 57, its perpendicular breadth $5\frac{1}{4}$, and the height of the parallelopiped 13, its volume $=57\times 5{\cdot}25\times 13=2525{\cdot}25$.

29. (ii.) *Given the edges of a parallelopiped, and their inclinations, to find its volume.*—Let AM be the parallelopiped, DE a perpendicular from D upon BC; and let a spherical surface whose centre is A, cut the faces of the parallelopiped in the arcs FH, FG, GH, and the plane ADE in the arc HI.



Let AB $=a$, AC $=b$, AD $=c$, and the angles BAC $=\alpha$, BAD $=\beta$, CAD $=\gamma$. In the spherical triangle FGH,

$$\sin F=\frac{2}{\sin\alpha\sin\beta}\sqrt{\{\sin s\sin(s-\alpha)\sin(s-\beta)\sin(s-\gamma)\}},$$

$$\text{where}\quad s=\tfrac{1}{2}(\alpha+\beta+\gamma),$$
$$\text{and}\ \sin HI=\sin\beta\sin F;$$

also $DE=AD\sin DAE=c\sin HI=c\sin\beta\sin F$;

and the parallelopiped

$$=\text{parallelogram } BC\times DE=DE\times ab\sin\alpha\ \text{(art. 8)};$$

therefore the volume

$$=2abc\sqrt{\{\sin s\sin(s-\alpha)\sin(s-\beta)\sin(s-\gamma)\}}.$$

Example.—The edges of a parallelopiped are 4, 5, and 6, and their inclination 40°, 50°, and 60°. Find the volume.

$$\begin{array}{rcrlr}
\alpha & = & 40^\circ & & \\
\beta & = & 50 & & \\
\gamma & = & 60 & & \\
\hline
 & & 150 & & \\
S & = & 75 & \log\sin = & \bar{1}{\cdot}9849438 \\
s-\alpha & = & 35 & \ldots = & \bar{1}{\cdot}7585913 \\
s-\beta & = & 25 & \ldots = & \bar{1}{\cdot}6259483 \\
s-\gamma & = & 15 & \ldots = & \bar{1}{\cdot}4129962 \\
\hline
 & & & 2) & \bar{2}{\cdot}7824796 \\
\hline
 & & & & \bar{1}{\cdot}3912398 \\
a & = & 4 & \log a = & {\cdot}6020600 \\
b & = & 5 & \log b = & {\cdot}6989700 \\
c & = & 6 & \log c = & {\cdot}7781513 \\
 & & & \log 2 = & {\cdot}3010300 \\
\hline
\end{array}$$

Volume $=59{\cdot}0814$ log volume $=1{\cdot}7714511$

30. *The Surface of the Parallelopiped.*—From art. 8 the surface is evidently

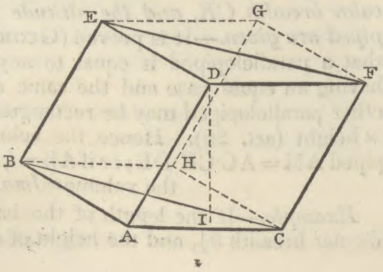
$$=2(ab\sin\alpha+ac\sin\beta+bc\sin\gamma).$$

Example.—Find the surface of the parallelopiped in example to art. 29.

$$a=4,\ b=5,\ c=6,\ \alpha=40^\circ,\ \beta=50^\circ,\gamma=60^\circ.$$

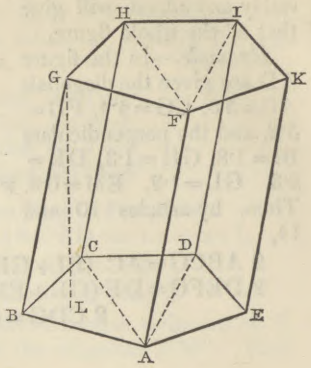
$$\begin{array}{rlrl}
\text{Log } a = & {\cdot}6020600 & \therefore\ BC = & 12{\cdot}856 \\
\log b = & {\cdot}6989700 & \text{similarly } BD = & 18{\cdot}385 \\
4\sin\alpha = & 9{\cdot}8080675 & \text{and } CD = & 25{\cdot}981 \\
\hline
\text{Log area } BC = & 1{\cdot}1090975 & & 57{\cdot}222 \\
 & & \therefore\ \text{Surface} = & 114{\cdot}444
\end{array}$$

31. *To find the Volume of a Prism.*—If the parallelopiped AG be cut by a plane BEFC, it will be divided into two equal prisms (GEOMETRY, p. 536, theor. iv.; *Euc.* xi. 28). Therefore the prism AEF $=\tfrac{1}{2}$AG $=\tfrac{1}{2}$ABHC × DI (art. 28) = ABC × DI.



If the prism be polygonal, it may be divided into triangular prisms, as shown in the figure; and its volume is equal to the sum of these prisms.

$$=ABC\times FL+ACD\times FL$$
$$+ADE\times FL$$
$$=ABCDE\times FL.$$



Hence, in any prism, if m^2 = area of base, and h = perpendicular height,

$$\text{the volume}=m^2h\,;$$

or the volume of any prism is equal to its base multiplied by its height.

Example.—The sides of the base of a triangular prism are 3, 4, and 5 feet, and its height 7 feet. What is its volume?

The area of the base = 6 square feet (ex. 1, art. 12);
Therefore the volume $=6\times 7=42$ cubic feet.

32. *To find the Surface of a Prism.*—The surface will be obtained by adding the areas of the triangles or polygons which form the ends of the solid, and of the parallelograms which form its sides.

If the edges are perpendicular to the base, it is evident (art. 6) that if p = the perimeter of the base, and h = the height, the lateral surface $=ph$;

and m^2 being the area of the end, the whole surface

$$=ph+2m^2.$$

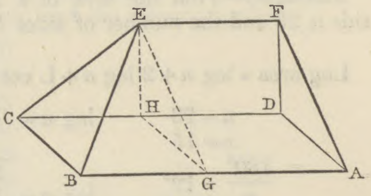
Example.—Find the volume and surface of a prism whose base is a regular polygon of 15 sides, a side of the base 23 feet, and the height 75 feet.

The area of the base $=9332{\cdot}8$ square feet (ex. art. 22);
Therefore the volume $=75\times 9332{\cdot}8=699960$ cubic feet.

Also if the edges are perpendicular to the base, the surface

$$=2\times 9332{\cdot}8+15\times 23\times 75$$
$$=44540{\cdot}6 \text{ square feet.}$$

33. *To find the Volume of a Wedge.*—The base AC of the wedge is a parallelogram, and the edge EF is parallel to AB or CD. If the plane EHG be parallel to ADF, the wedge will be equal to the sum or difference of the prism AEHG, and the pyramid CEG.



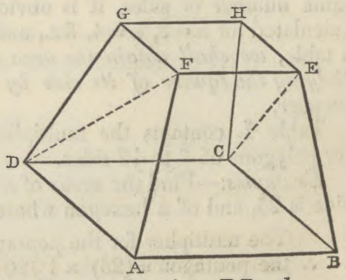
Therefore, if AB $=a_1$, EF $=a_2$, a perpendicular from A upon CD $=b$, and a perpendicular from F upon the plane AC $=h$, the wedge

$$=\tfrac{1}{2}AG\times bh\pm\tfrac{1}{3}BG\times bh\ \text{(arts. 31 and 35)}$$
$$=\tfrac{1}{2}a_2bh\pm\tfrac{1}{3}(a_1\ a_2)\,bh=bh\left(\frac{a_2}{2}+\frac{a_1-a_2}{3}\right)$$
$$=\tfrac{1}{6}bh(2a_1+a_2).$$

Example.—The length and breadth of the base of a wedge are 32 and 9, and the height 28 feet.

$$\text{The volume}=\tfrac{1}{6}\times 9\times 28\,(64+21)=3570.$$

34. *To find the Volume of a Rectangular Prismoid.*—The faces BD and GE are rectangles, whose planes and sides are parallel; hence the figure is evidently a frustum of a pyramid.



Let AB $=a_1$, AD $=b_1$, EF $=a_3$, FG $=b_3$, and the perpendicular from F upon the plane DB $=h$.

The prismoid = wedge AED + wedge DEH

$$=\tfrac{1}{6}b_1h(2a_1+a_3)+\tfrac{1}{6}b_3h(2a_3+a_1)$$
$$=\tfrac{1}{6}h\{a_1b_1+a_3b_3+(a_1+a_3)(b_1+b_3)\}.$$

But if the figure were cut by a plane parallel to, and equidistant from the planes AC, EG, and if a_2, b_2 be the length and breadth of this plane reckoned respectively parallel to AD, AB,

$$\text{then } a_2=\frac{a_1+a_3}{2};\ b_2=\frac{b_1+b_3}{2}.$$

Hence substituting

$$\text{the prismoid}=\tfrac{1}{6}h\,(a_1b_1+4a_2b_2+a_3b_3).$$

Since a_1b_1, a_2b_2, a_3b_3, are the areas of the ends, and what may be termed the middle section of the figure parallel to the ends, *the volume of the prismoid is obtained by adding together the areas of its ends, and four times the area of its middle section, and multiplying the sum by one-sixth of the height.*

Example.—The sides of the base of a rectangular prismoid are 12 and 8; the sides of the top respectively parallel to those of the base are 6 and 4; and the height is 5.

$$\text{Here } a_1=12,\ a_3=6,\ b_1=8,\ b_3=4,\ h=5.$$

$$a_2=\frac{a_1+a_3}{2}=9;\quad b_2=\frac{b_1+b_3}{2}=6.$$

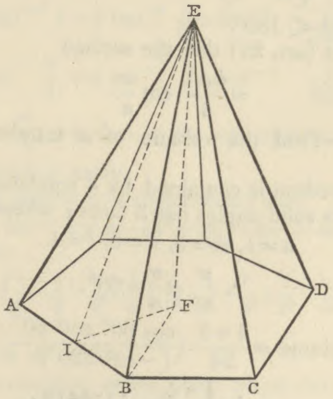
$$\text{The volume}=\tfrac{5}{6}(12\times 8+4\times 9\times 6+4\times 6)=280.$$

35. *To find the Volume of any Pyramid.*—The volume of a pyramid is one-third of that of a prism of the same base and altitude (Geom. p. 539, theor. 17, cor. 1; *Euclid* xii. 7, cor. 1). It therefore follows (art. 31) that if a^2 = the base, and h = the height,

$$\text{the volume}=\tfrac{1}{3}m^2h;$$

or the volume is one-third of the product of the base multiplied by the height.

36. *To find the Volume of a Right Pyramid.*—The base AD is supposed to be a regular polygon; F is the centre of a circle described about the polygon AD, and EF is perpendicular to the plane AD. EI, perpendicular to AB, is the "slant height."



Let AB = a, EF = h, EI = l, n = the number of sides of the polygon.

$$\text{The area AD}=\tfrac{1}{4}na^2\cot\frac{180^\circ}{n}\ \text{(art. 22)};$$

and hence, since (art. 35) the pyramid = ⅓AD, EF,

$$\text{its volume}=\tfrac{1}{12}na^2h\cot\frac{180^\circ}{n}.$$

37. *To find the Surface of a Right Pyramid.*—The lateral surface of the pyramid $=n\text{ABE}=n\text{AI}\cdot\text{EI}=\tfrac{1}{2}nal$.

$$\text{Hence the whole surface}=\tfrac{1}{2}na\left(l+\tfrac{1}{2}a\cot\frac{180^\circ}{n}\right).$$

In the triangle EFI,

$$\text{EI}^2=\text{EF}^2+\text{FI}^2=\text{EF}^2+\text{IB}^2\cot^2\text{BFI},$$

$$\therefore\ l^2=h^2+\tfrac{1}{4}a^2\cot^2\frac{180^\circ}{n};$$

by which, according to the data given for calculating the surface and volume of the pyramid, we may obtain l from h, or h from l.

Example.—Find the volume and surface of an hexagonal pyramid, each side of the base being 2 feet 6 inches, and the length of the axis 10 feet.

$$a=2{\cdot}5,\ h=10,\ n=6;\ \therefore\ \frac{180^\circ}{n}=30^\circ.$$

$$\begin{array}{rr}
\text{Log }\tfrac{1}{2}a= & {\cdot}0969100\\
\text{L Cot }30^\circ= & 10{\cdot}2385606\\
\hline
 & {\cdot}3354706\\
 & 2\\
\hline
\log\tfrac{1}{4}a^2\cot^2\dfrac{180^\circ}{n}= & {\cdot}6709412
\end{array}
\qquad
\begin{array}{rl}
\text{hence }\tfrac{1}{4}a^2\cot^2\dfrac{180^\circ}{n}= & 4{\cdot}687\\
h^2= & 100{\cdot}000\\
\hline
l^2= & 104{\cdot}687\\
l= & 10{\cdot}23
\end{array}$$

$$\text{Lateral surface}=3\times 2{\cdot}5\times 10{\cdot}23=76{\cdot}725\text{ sq. feet}$$

$$\begin{array}{rr}
\log a= & {\cdot}3979400\\
 & 2\\
\hline
 & {\cdot}7958800\\
\log n= & {\cdot}7781513\\
\text{L Cot }30^\circ= & 10{\cdot}2385606\\
\text{colog }4= & 9{\cdot}3979400\\
\hline
\text{Log area of base}= & 1{\cdot}2105319
\end{array}
\qquad
\begin{array}{rl}
\text{area of base}= & 16{\cdot}238\\
\hline
\text{whole surf.}= & 92{\cdot}963\text{ sq. feet}\\
\hline
\text{log base}= & 1{\cdot}2105319\\
\log h= & 1{\cdot}0000000\\
\text{colog }3= & 9{\cdot}5228787\\
\hline
\text{log volume}= & 1{\cdot}7334106\\
\text{volume}= & 54{\cdot}126\text{ cubic feet.}
\end{array}$$

38. *To find the Volume of the Frustum of any Pyramid.*—Let the pyramid ACF be cut by a plane abc parallel to the base ABC, and let AB = a_1, $ab=a_2$; the areas ACB = m_1^2, $acb=m_2^2$; the heights FG = h_1, FH = h_2, GH = h. Then the frustum AcB

= pyramid ACF − pyramid abc

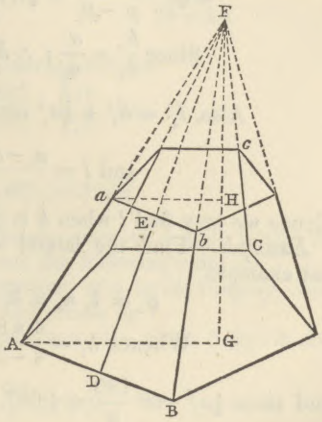
$$=\tfrac{1}{3}m_1^2h_1-\tfrac{1}{3}m_2^2h_2\ \text{(art. 35)}.$$

$$\text{But }\frac{h_1}{h_2}=\frac{\text{AF}}{a\text{F}}=\frac{a_1}{a_2};$$

$$\therefore\ \frac{h_1}{h}=\frac{a_1}{a_1-a_2}=\frac{m_1}{m_1-m_2}.$$

$$\text{Hence }h_1=\frac{m_1h}{m_1-m_2},$$

$$\text{and }h_2=\frac{m_2h}{m_1-m_2}.$$



Therefore the volume of the frustum

$$=\tfrac{1}{3}h\cdot\frac{m_1^3-m_2^3}{m_1-m_2}=\tfrac{1}{3}h(m_1^2+m_1m_2+m_2^2);$$

a formula which applies to the frusta of all pyramids whether *right* or *oblique.*

39. The formula of article 38 may be put into a somewhat different form.—If AB = a_1, $ab=a_3$; area AC = m_1^2, area $ac=m_3^2$; and if a_2 m_2^2 be the side and area of the *middle section* of the frustum formed by a plane parallel to, and equidistant from, the planes AC, ac, we shall evidently have (*Euc.* vi. 20, cor. 3)—

$$m_1^2=c^2a_1^2,\ m_2^2=c^2a_2^2,\ m_3^2=c^2a_3^2;$$

where c depends on the nature of the polygon AD.

$$\text{Also } a_2=\tfrac{1}{2}(a_1+a_3);$$

$$\text{therefore } 4m_2^2=c^2(a_1+a_3)^2=c^2a_1^2+2c^2a_1a_3+c^2a_3^2$$
$$=m_1^2+2m_1m_3+m_3^2.$$

Now the volume of the frustum

$$=\tfrac{1}{6}h(2m_1^2+2m_1m_3+2m_3^2)^2\ \text{(art. 37)}.$$

Whence substituting

$$\text{the volume}=\tfrac{1}{6}h\,(m_1^2+4m_2^2+m_3^2);$$

or the volume of the frustum of a pyramid is obtained by adding the areas of the ends to four times the area of the *middle section, and multiplying the sum by one-sixth of the height.*

Example.—Find the volume of the frustum of an hexagonal pyramid, the sides of whose terminating polygons are 4 and 3 feet, and its height 9 feet.

(i.) By the formula of article 38.—By art. 22 we find $m_1^2 = 41{\cdot}569$, and $m_2^2 = 23{\cdot}383$.

$$\text{Whence } m_1 m_2 = 31{\cdot}177\,;$$
$$\text{and the volume } = 3\,(41{\cdot}569 + 31{\cdot}177 + 23{\cdot}383)$$
$$= 288{\cdot}39 \text{ cubic feet.}$$

(ii.) By the formula of article 39.—The side of the middle section, $a_2 = \frac{1}{2}(4+3) = 3{\cdot}5$.

Whence (art. 22) $m_2^2 = 31{\cdot}826$;

$$\text{and the volume } = \tfrac{3}{2}(41{\cdot}569 + 127{\cdot}304 + 23{\cdot}383)$$
$$= 288{\cdot}39 \text{ cubic feet.}$$

40. *To find the Surface of the Frustum of a Right Pyramid.*—In fig. art. 38 let the perimeter of AC $= p_1$, and that of $ac = p_2$; and the slant heights DF $= l_1$, EF $= l_2$, DE $= l$, AB $= a_1$, $ab = a_2$; then the lateral surface of the frustum is equal to the difference of the lateral surfaces of the pyramids AFC, $afc = \frac{1}{2}p_1 l_1 - \frac{1}{2}p_2 l_2$.

$$\text{But } \frac{l_1}{l_2} = \frac{a_1}{a_2}. \quad \therefore \frac{l_1}{l} = \frac{a_1}{a_1 - a_2} = \frac{p_1}{p_1 - p_2}.$$

$$\text{Hence } l_1 = \frac{p_1 l}{p_1 - p_2}, \text{ and } l_2 = \frac{p_2 l}{p_1 - p_2}\,;$$

Therefore the lateral surface of the frustum

$$= \tfrac{1}{2}l \cdot \frac{p_1^2 - p_2^2}{p_1 - p_2} = \tfrac{1}{2}l(p_1 + p_2).$$

$$\text{Since } \frac{h_1}{h_2} = \frac{a_1}{a_2}\,; \; \therefore h_1 = \frac{a_1 h}{a_1 - a_2}.$$

$$\text{Also, } l_1^2 = h_1^2 + \tfrac{1}{4}a_1^2 \cot^2 \frac{180^\circ}{n} \text{ (art. 37)};$$

$$\text{and } l = \frac{a_1 - a_2}{a_1} l_1.$$

Hence we may find l when h is given.

Example.—Find the lateral surface of the frustum in last example.

$$a_1 = 4,\; a_2 = 3,\; h = 9.$$

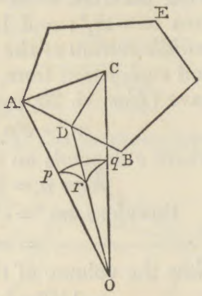
$$\text{Whence } h_1 = \frac{4 \times 9}{4 - 3} = 36\,;$$

and since $\frac{1}{4}a_1^2 \cot^2 \frac{180}{n} = 4{\cdot}687$, we have

$$l_1 = 36{\cdot}07, \text{ and } l = \frac{(4-3) \times 36{\cdot}07}{4} = 9{\cdot}0175.$$

Hence lateral surface $= 3(4+3) \times 9{\cdot}0175 = 189{\cdot}37$ square feet.

41. *To find the Volume and Surface of a Regular Polyhedron.*—Regular polyhedrons are solids contained by planes, which are equal, similar, and regular polygons; each solid angle of the polyhedron is contained by the same number of planes, having the same inclinations, and the polyhedron admits of having a sphere inscribed within it, or described about it. There are only five regular polyhedrons, which are enumerated in Table II.



Let ABE be one of the faces of the polyhedron, O the centre of a circumscribed sphere, and OC, OD perpendiculars to the plane ABE and to the line AB: then it is evident that AO and OC are the radii of spheres described about the polyhedron, and inscribed within it; that AB is bisected in D, and that C is the centre of the polygon ABE.

If l = the number of faces in the polyhedron,
m = the number of faces in each of its solid angles,
n = the number of sides in each of its faces, and
a = AB, the length of each of those sides;

and if we suppose the planes ACO, ADO, CDO, to meet the surface of a sphere whose centre is O in the arcs pq, pr, qr,

$$\text{the angles, } p = \frac{\pi}{m},\; q = \frac{\pi}{n},\; r = \frac{\pi}{2}\,;$$

and in the spherical triangle pqr,

$$\cos \text{AOC} = \cot p \cot q = \cot \frac{\pi}{m} \cot \frac{\pi}{n}$$

$$\text{whence } \cot \text{AOC} = \frac{\cos \frac{\pi}{m} \cos \frac{\pi}{n}}{\left\{ -\cos\left(\frac{\pi}{m} + \frac{\pi}{n}\right) \cos\left(\frac{\pi}{m} - \frac{\pi}{n}\right) \right\}^{\frac{1}{2}}}$$

Also CO = AC cot AOC = AD cosec ACD cot AOC,

$$= \tfrac{1}{2}a \operatorname{cosec} \frac{\pi}{n} \cot \text{AOC}\,;$$

$$\text{and the polygon ABE} = \frac{na^2}{4} \cot \frac{\pi}{n} \text{ (art. 22).}$$

Now, as the polyhedron is made up of l equal pyramids, whose bases and altitudes are respectively the same as the polygon ABE and the line CO,

$$\text{its volume} = \tfrac{1}{3}l \cdot \text{CO} \cdot \text{AEB (art 35.)},$$

$$= \frac{nla^3}{24} \cdot \frac{\cos \frac{\pi}{m} \cdot \cot^2 \frac{\pi}{n}}{\left\{ -\cos\left(\frac{\pi}{m} + \frac{\pi}{n}\right) \cos\left(\frac{\pi}{m} - \frac{\pi}{n}\right) \right\}^{\frac{1}{2}}} :$$

a form apparently impossible, but not really so; for in every polyhedron $\cos\left(\frac{\pi}{m} + \frac{\pi}{n}\right)$ is negative, the angle $\frac{\pi}{m} + \frac{\pi}{n}$ being $> 90^\circ$ and $< 180^\circ$.

It is evident (art. 22) that the surface

$$= \frac{lna^2}{4} \cdot \cot \frac{\pi}{n}.$$

Example.—Find the volume of a tetrahedron whose edge is 1.

The tetrahedron is contained by 4 equilateral triangles and each of its solid angles has 3 faces; whence

$$a = 1,\; m = 3,\; n = 3,\; l = 4$$

$$\therefore \frac{\pi}{m} = \frac{\pi}{n} = 60^\circ.$$

$$\text{Hence the volume } = \frac{4 \times 3}{24} \cdot \frac{\cos 60^\circ \cot^2 60^\circ}{(-\cos 120^\circ)^{\frac{1}{2}}}.$$

$$= \tfrac{1}{2} \cdot \frac{\frac{1}{2} \times \frac{1}{3}}{\frac{1}{\sqrt{2}}} = \cdot 1178513\,;$$

$$\text{and the surface} = \frac{3 \cdot 4}{4} \cot 60^\circ$$
$$= \sqrt{3} = 1{\cdot}7320508.$$

42. It obviously follows from the formulæ of last article, that the surface and volume of a polyhedron whose edge is a, may be obtained by multiplying the surface and volume of a similar polyhedron, whose edge is 1, by a^2 and a^3 respectively. The surfaces and volumes of the five regular polyhedrons, whose edges = 1, are given in table II.

Example.—Find the surface and volume of a regular dodecahedron whose edge is 5.

The tabular surface and volume from table II. are 20·6457788 and 7·6631189.

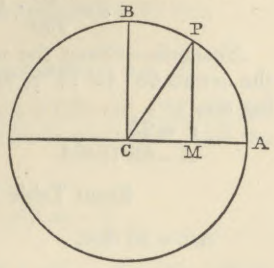
The surface $= 25 \times 20{\cdot}6457788 = 516{\cdot}14447$.
The volume $= 125 \times 7{\cdot}6631189 = 957{\cdot}88986$.

Mensuration.

SECTION III.—THE CIRCLE.

The Circumference of a Circle.

43. If CP$=r$, CN$=x$, MP$=y$, the equation to the circle is $x^2+y^2=r^2$;



$$\therefore \frac{dy}{dx}=-\frac{x}{y},$$

and the length of the arc AP

$$=\int_0^x\left(1+\frac{dy^2}{dx^2}\right)^{\frac{1}{2}}dx$$

$$=r\int_0^x\frac{dx}{(r^2-x^2)^{\frac{1}{2}}}$$

$$=r\left(\frac{x}{r}+\tfrac{1}{2}\cdot\frac{x^3}{3r^3}+\frac{1\cdot3}{2\cdot4}\cdot\frac{x^5}{5r^5}+\&c.\right)$$

Putting $x=r$, the length of the quadrant AP

$$=r\left(1+\frac{1}{2\cdot3}+\frac{1\cdot3}{2\cdot4\cdot5}+\frac{1\cdot3\cdot5}{2\cdot4\cdot6\cdot7}+\&c.\right)$$

44. A very rapidly converging series for the circumference of a circle is obtained by the following process.

It is shown in Trigonometry, that

$$\tan^{-1}m+\tan^{-1}n=\tan^{-1}\frac{m-n}{1+mn};$$

$$\therefore \tan^{-1}1-\tan^{-1}\frac{1}{5}=\tan^{-1}\frac{1-\frac{1}{5}}{1+\frac{1}{5}}=\tan^{-1}\frac{2}{3}$$

$$\tan^{-1}\frac{2}{3}-\tan^{-1}\frac{1}{5}=\tan^{-1}\frac{\frac{2}{3}-\frac{1}{5}}{1+\frac{2}{15}}=\tan^{-1}\frac{7}{17}$$

$$\tan^{-1}\frac{7}{17}-\tan^{-1}\frac{1}{5}=\tan^{-1}\frac{\frac{7}{17}-\frac{1}{5}}{1+\frac{7}{85}}=\tan^{-1}\frac{9}{46}$$

$$\tan^{-1}\frac{9}{46}-\tan^{-1}\frac{1}{5}=\tan^{-1}\frac{\frac{9}{46}-\frac{1}{5}}{1+\frac{9}{230}}=\tan^{-1}\frac{-1}{239}$$

Whence, adding,

$$\tan^{-1}1-4\tan^{-1}\frac{1}{5}=\tan^{-1}\frac{-1}{239},$$

$$\text{or}\quad\frac{\pi}{4}=4\tan^{-1}\frac{1}{5}-\tan^{-1}\frac{1}{239};$$

for $\tan^{-1}1=\frac{\pi}{4}$; where π is the circumference of a circle whose diameter is *unity*.

Now, it is proved in Trigonometry that

$$\tan^{-1}x=x-\tfrac{1}{3}x^3+\tfrac{1}{5}x^5-\tfrac{1}{7}x^7+\&c.$$

Therefore,

$$\frac{\pi}{4}=4\left(\frac{1}{5}-\frac{1}{3}\cdot\frac{1}{5^3}+\frac{1}{5}\cdot\frac{1}{5^5}-\frac{1}{7}\cdot\frac{1}{5^7}+\frac{1}{9}\cdot\frac{1}{5^9}-\&c.\right)$$
$$-\left(\frac{1}{239}-\frac{1}{3}\cdot\frac{1}{239^3}+\&c.\right);$$

a rapidly converging series, from which the value of π is calculated as follows:—

$$\begin{array}{rr@{\qquad}rr}
\frac{1}{5}= & \cdot200000000 & -\frac{1}{3}\cdot\frac{1}{5^3}= & -\cdot002666666 \\
\frac{1}{5}\cdot\frac{1}{5^5}= & \cdot000064000 & -\frac{1}{7}\cdot\frac{1}{5^7}= & -\cdot000001828 \\
\cline{4-4}
\frac{1}{9}\cdot\frac{1}{5^9}= & \cdot000000057 & & -\cdot002668494 \\
\cline{2-2}
 & \cdot200064057 & & \\
 & -\cdot002668494 & -\frac{1}{239}= & -\cdot004184100 \\
\cline{2-2}
 & \cdot197395563 & \frac{1}{3}\cdot\frac{1}{239^3}= & \cdot000000024 \\
\cline{4-4}
 & 4 & & -\cdot004184076 \\
\cline{2-2}
 & \cdot789582252 & & \\
 & -\cdot004184076 & & \\
\cline{2-2}
\frac{\pi}{4}= & \cdot785398176 & & \\
 & 4 & & \\
\cline{2-2}
\pi= & 3\cdot141592704, & &
\end{array}$$

which is correct to 7 places.

Mensuration.

The value of π to 20 places of decimals is

3·14159265358979323846.

The functions of π, which are most frequently useful in Mensuration, will be found in Table III.

45. Since π is the circumference of a circle whose diameter is unity; and since the circumference of circles are proportional to their radii, or to their diameters. (See TRIGONOMETRY.)

therefore if r = the radius; d=the diameter;
the circumference of the circle$=\pi d=2\pi r$.

Whence the following rules:—

(i.) *To find the circumference of a circle*, multiply the diameter, or twice the radius, by 3·14159..., or 3·1416.

Example 1.—The circumference of a circle whose diameter is 5 feet

$$=5\times3\cdot1415927=15\cdot7079635 \text{ feet.}$$

Example 2.—Find the circumference of the earth at the equator, the equatorial diameter being 7925·6 miles.

$$\begin{array}{rr}
\text{Log } 7925\cdot6= & 3\cdot8990321 \\
\log \pi= & \cdot4971499 \\
\cline{2-2}
\text{Circumference} = 24899\cdot0 \text{ miles.} & 4\cdot3961820
\end{array}$$

46. If we convert the value of π into a continued fraction we obtain

$$\frac{314159}{100000}=3+\cfrac{1}{7+\cfrac{1}{15+\cfrac{1}{1+\cfrac{1}{25+\&c.}}}}$$

Of which the successive convergents are

$$\frac{22}{7},\quad\frac{333}{106},\quad\frac{355}{113},\ \&c.$$

Of these

$$\frac{355}{113}=3\cdot1415929,$$

which differs from the accurate value of π only in the 7th place of decimals. Whence the following rules:—

(ii.) *To find the circumference of a circle roughly, multiply the diameter by* 22, *and divide by* 7.

Example.—The circumference of a circle 5 feet in diameter is about

$$5\times\frac{22}{7}-15\cdot71;$$

which is correct only in one place of decimals.

(iii.) *To find the circumference of a circle very nearly, multiply the diameter by* 355, *and divide by* 113.

Example.—The circumference of a circle whose diameter is 5 is

$$\frac{5\times355}{113}=15\cdot7079645;$$

a result correct in 5 places of decimals.

(iv.) *To multiply by π. Multiply by* 22 *and divide by* 7, *and from the result subtract $\frac{1}{8}$th of $\frac{1}{100}$th of the multiplicand.*—The result is too great by about its 200,000th part.

Example.—Find the circumference in last example.

$$\begin{array}{rr@{\qquad}l}
 & 5 & 100)\,5 \\
 & 22 & 8)\cdot05 \\
\cline{2-2}
 & 7)\,110 & \quad\cdot00625 \\
\cline{2-2}
 & 15\cdot714285 & \\
 & 006250 & \\
\cline{2-2}
\text{Circumference}= & 15\cdot708035 &
\end{array}$$

47. *To find the diameter of a Circle when the Circumference is given.*

(i.) It follows from article 45, that *to find the diameter we must divide the circumference* by 3·14159, or multiply by ·31830986184.

Or if c = the circumference of the circle,

$$d=\frac{c}{\pi};\quad r=\frac{c}{2\pi}.$$

Example.—The diameter of the circle whose circumference is 15·70796

$$=15{\cdot}70796\times{\cdot}3183098=4{\cdot}999998=5\text{ nearly.}$$

(ii.) *To find the diameter roughly, multiply the circumference by* 7, *and divide by* 22.

(iii.) *To find the diameter nearly, multiply the circumference by* 113, *and divide by* 355.

(iv.) *To divide by* π, *multiply by* 7, *divide by* 11 *and by* 2, *and to the result add* $\frac{1}{8}$*th of* $\frac{1}{1000}$*th of the dividend.* The result is too small by about its 100,000th part.

Example.—Find the diameter in last example.

$$\begin{array}{r} 15{\cdot}707964 \\ 7 \\ \hline 11)\overline{109{\cdot}955748} \\ \hline 2)\overline{9{\cdot}995977} \\ \hline 4{\cdot}997989 \\ {\cdot}001964 \\ \hline 4{\cdot}999953 \end{array}=\text{the diameter.}\qquad \begin{array}{r} 1000)\overline{15{\cdot}707964} \\ 8)\overline{{\cdot}015708} \\ \hline {\cdot}001964 \end{array}$$

Arcs of Circles.

48. Since angles at the centres of circles are proportional to the arcs on which they stand (GEOM. sec. iv., theor. 31; or *Euc.* vi. 33),

if A = the number of degrees in the angle at the centre;
r = the radius,
a = the arc which subtends the angle A,

$$\pi r : a :: 180^\circ : \mathrm{A};$$

$$\therefore\ \mathrm{A}=\frac{180^\circ}{\pi}\cdot\frac{a}{r};$$

$$\text{or }\mathrm{A}=57{\cdot}2957795\times\frac{a}{r}.$$

From this equation the following rules are obtained:—

49. (i.) *To find the number of degrees in an arc when its length and the radius of the circle are given, multiply the length of the arc by* 57·29578, *and divide by the radius.*

Example.—If the radius of a circle be 25 and the arc 30, the number of degrees in the arc

$$=57{\cdot}29578\times\frac{30}{25}=68^\circ{\cdot}75494=68^\circ\ 45'\ 17''{\cdot}8;$$

or, by logarithms,

$$\begin{array}{rl} \text{From Table III. } \log\frac{180}{\pi} & =1{\cdot}7581226 \\ a=30\quad \log a & =1{\cdot}4771213 \\ r=25\quad \text{colog } r & =8{\cdot}6020600 \\ \hline \mathrm{A}=68^\circ{\cdot}75494\qquad \log \mathrm{A} & =1{\cdot}8373039 \\ =68^\circ\ 45'\ 17''{\cdot}8. & \end{array}$$

50. (ii.) *To find the radius of the circle when the length of the arc and the number of degrees which it contains are given, multiply the length of the arc by* 57·29578, *and divide by the number of degrees in the angle.*

For, by the formula (art. 48.),

$$r=57{\cdot}2957795\times\frac{a}{\mathrm{A}}.$$

Example.—The length of the arc is 30 feet, and the angle, which it subtends at the centre, 68° 45′ 17″·8. Find the radius of the circle.

$$\begin{array}{ll} a=30 & \log\frac{180}{\pi}=1{\cdot}7581226 \\ \mathrm{A}=68^\circ\ 45'\ 17''{\cdot}8 & \log a\ \ =1{\cdot}4771213 \\ \quad =68{\cdot}75494 & \text{colog}\,\mathrm{A}=8{\cdot}1626961 \\ & \log r\ \ =\overline{1{\cdot}3989400} \end{array}$$

Hence the radius = 25 feet.

51. (iii.) *To find the arc when the radius and the angle subtended at the centre are given, multiply the number of degrees in the angle by the radius and by* ·0174533. For, by the formula of art. 48,

$$a=\frac{\pi}{180}\cdot \mathrm{A}r={\cdot}0174533\times \mathrm{A}r.$$

Example.—Given the radius 25 feet, and the angle at the centre 68° 45′ 17″·8, to find the length of the subtending arc.

$$\begin{array}{lrl} r\ =25 & \log r & =1{\cdot}3979400 \\ \mathrm{A}-68{\cdot}75494 & \log \mathrm{A} & =1{\cdot}8373039 \\ & \text{From Table III. }\log\frac{\pi}{180} & =\bar{2}{\cdot}2418774 \\ \text{Arc}=30\text{ feet.} & \log a & =\overline{1{\cdot}4771213} \end{array}$$

Since the length of an arc $=\frac{\pi \mathrm{A}}{180}\times$ radius; if $\frac{\pi \mathrm{A}}{180}$ (or the length of an arc to radius = 1) be computed for the various values of A, and arranged in a table (See Table IV.), the length of any arc may be found by multiplying the proper tabular number by the radius of the arc.

Example.—To find the length of an arc whose radius is 25, and angle 68° 45′ 17″·8.

$$\begin{array}{rr} \text{From Table IV. arc of }60^\circ= & 1{\cdot}0471976 \\ 8^\circ= & {\cdot}1396263 \\ 40'= & 116355 \\ 5'= & 14544 \\ 10''= & 485 \\ 7''= & 339 \\ 0''{\cdot}8= & 39 \\ \hline & 1{\cdot}2000001 \end{array}$$

∴ Arc to radius 25 = 1·2 × 25 = 30.

A great variety of problems in finding the lengths of arcs may be proposed. The following seem to be the most important:—

52. (iv.) *To find the length of an arc whose chord and radius are given.*—In fig. art. 22 we have given AC = r, AB = $2c$.

To find the length of the arc AEB. Put the angle ACB = A, then $\sin\frac{\mathrm{A}}{2}=\frac{c}{r}$; whence A is known, and the length of the arc is found by art. 51.

Example.—The chord of an arc is 28·23214 feet, and the radius 25 feet. Find the length of the arc.

$$\begin{array}{ll} \text{Here } c=14{\cdot}11607 & \log c\ \ =1{\cdot}1497136 \\ \quad r=25 & \log r\ \ =\underline{1{\cdot}3979400} \\ \therefore\ \frac{\mathrm{A}}{2}=34^\circ\ 22'\ 38''{\cdot}9 & \text{L}\sin\frac{\mathrm{A}}{2}=9{\cdot}7517736 \\ \text{and }\mathrm{A}=68^\circ\ 45'\ 17''{\cdot}8 & \end{array}$$

Having ascertained A, we find, by art. 51, that the length of the arc is 30 feet.

53. *To find the Length of an Arc when its Chord, and Height, or Versed Sine, are given.*—In fig. art. 22, putting DE = h;

$$\because\ \mathrm{AC}^2=\mathrm{AD}^2+\mathrm{CD}^2;\ \therefore\ r^2=c^2+(r-h)^2:$$

$$\text{Hence } r=\tfrac{1}{2}\left(h+\frac{c^2}{h}.\right)$$

The radius r being known, the length of the arc is found by art. 52.

Example.—Given the chord of an arc 28·23214 feet, and its versed sine 4·36661, to find its length.

$$\begin{array}{ll} c\ =14{\cdot}11607 & \log c=1{\cdot}1497136 \\ & \qquad\qquad\quad 2 \\ & \log c^2=2{\cdot}2994272 \\ h=\ 4{\cdot}3666 & \log h=\ {\cdot}6401444 \\ \frac{c^2}{h}=45{\cdot}6334 & \log\frac{c^2}{h}=1{\cdot}6592828 \\ \hline 50{\cdot}0000 & \end{array}$$

The radius r = 25·0.

Mensuration.

We have now $\sin A = \frac{c}{r}$ (art. 52),

whence $A = 68°·75494$;

and finally, by art. 52, the arc is found to be 30 feet.

The Area of a Circle.

54. In the figure to article 43, if $CP = r^2$, $CM = x$, and $MP = y$, the equation to the circle is $x^2 + y^2 = r^2$, and the area of the quadrant ABC.

$$= \int_0^r y dx = \int_0^r (r^2 - x^2)^{\frac{1}{2}} dx = \frac{\pi r^2}{4}$$

Whence the area of the circle $= \pi r^2$. See also article 59.

55. A more elementary demonstration may be obtained as follows:—

The area of a circle is greater than that of any inscribed, and less than that of any circumscribed polygon; and by continually increasing the number of sides of the polygons, their areas will obviously approach to equality with each other, and with that of the circle.

Let AB, FG (fig. art. 22) be the sides of regular inscribed and circumscribed polygons,

n = the number of sides in each,
P = the area of the circumscribed polygon,
p = the area of the inscribed polygon.

Then putting θ for the angle ACB,

$$\theta = \frac{\pi}{n};$$

and, by continually increasing n, θ diminishes indefinitely, and ultimately

$$\frac{\tan \theta}{\theta} = \frac{\sin \theta}{\theta} = 1. \text{ (See TRIGONOMETRY.)}$$

$$\text{Now, } P = nr^2 \tan \frac{\pi}{n} = \pi r^2 \cdot \frac{\tan \frac{\pi}{n}}{\frac{\pi}{n}} \quad \text{(art. 25.)}$$

$$= \pi r^2 \cdot \frac{\tan \theta}{\theta} = \pi r^2 \text{ ultimately;}$$

$$\text{for } \frac{\tan \theta}{\theta} = 1 \text{ ultimately.}$$

$$\text{Also } p = nr^2 \sin \frac{\pi}{n} \cos \frac{\pi}{n} = \pi r^2 \cdot \frac{\sin \frac{\pi}{n}}{\frac{\pi}{r}} \cdot \cos \frac{\pi}{n} \quad \text{(art. 24.)}$$

$$= \pi r^2 \frac{\sin \theta}{\theta} \cdot \cos \theta = \pi r^2 \text{ ultimately;}$$

$$\text{for } \frac{\sin \theta}{\theta} = 1 \text{ and } \cos \theta = 1 \text{ ultimately.}$$

Therefore, since we have always

$$P > \text{area of circle} > p;$$

and since P and p both ultimately differ from πr^2 by less than any assignable quantity, it follows that

the area of the circle $= \pi r^2$.

56. If d be the diameter of the circle,

$$d = 2r, \text{ and area} = \frac{\pi}{4} d^2;$$

where $\frac{\pi}{4} = ·785398163397$,

again the area $= \pi r \cdot r$.

But if c = the circumference, $c = 2\pi r$,

therefore the area $= \frac{1}{2} cr = \frac{1}{2} c \times \frac{1}{2} d$.

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Lastly, the area $= \pi r^2 = \frac{4 \pi^2 r^2}{4 \pi} = \frac{c^2}{4 \pi}$,

where $\frac{1}{4 \pi} = ·07957747155$.

Whence the following rules:—

(i.) *The area of a circle is obtained by multiplying the square of the radius by* 3·14159.

Example.—The area of a circle whose radius is 3·5,

$$= (3·5)^2 \times 3·14159 = 12·25 \times 3·14159 = 38·4845.$$

(ii.) *The area of a circle is equal to the square of the diameter multiplied by* ·785398.

Example.—The area of a circle whose diameter is 7,

$$= 49 \times ·785398 = 38·4845.$$

(iii.) *The area of a circle is equal to half the diameter multiplied by half the circumference.*

Example.—The diameter of a circle is 7; find the area. By article 45, the circumference $= 21·9911486$;

therefore the area $= 3·5 \times 10·9955743 = 38·4845$.

(iv.) The area of a circle is equal to the square of the circumference multiplied by ·0795575.

Example.—The circumference being 21·9911486;

the area $= (21·9911486)^2 \times ·0795575 = 38·4845$.

57. In the formulæ of articles 55 and 56, if we put

C^2 = the area of the circle,

$$r = \frac{1}{\sqrt{\pi}} \cdot C \quad \text{where } \frac{1}{\sqrt{\pi}} = ·5641896$$

$$d = \frac{2}{\sqrt{\pi}} \cdot C \quad \text{where } \frac{2}{\sqrt{\pi}} = 1·1283792$$

$$c = 2\sqrt{\pi} \cdot C \quad \text{where } 2\sqrt{\pi} = 3·5449077.$$

Whence, to find the radius, diameter, or circumference of a circle when the area is given, multiply the square root of the area by ·5641896, 1·1283792, or 3·5449077 *respectively*

Example.—The area of a circle is 38·4845.

$\sqrt{38·4845} = 6·2036$
$\therefore$ radius $= 6·2036 \times ·5641896 = 3·5$
diameter $= 6·2036 \times 1·1283792 = 7·0$
circumference $= 6·2036 \times 3·5449077 = 21·9911$.

58. *To find the Area of a Circular Ring.*—The ring is a plane surface bounded by two circles, described one within the other, but not necessarily concentric. If r_1, r_2 be the outer and inner radii of the ring, its area

$$= \pi (r_1^2 - r_2^2) = \pi (r_1 + r_2)(r_1 - r_2).$$

Example.—Find the area of a ring whose outer and inner diameters are 10 and 6.

$$r_1 = 5 \text{ and } r_2 = 3;$$

$$\therefore \text{area} = 8 \times 2 \times 3·14159 = 50·2655.$$

59. *To find the Area of a Sector of a Circle.*—If r be the radius of the circle (fig. art. 43), and θ the angle ACP, then the area of the sector ACP

$$= \frac{1}{2} r^2 \int_0^\theta d\theta = \frac{1}{2} \theta r^2 = \frac{1}{2} \text{ arc} \times \text{radius}.$$

For the whole circle $\theta = 2\pi$;

$$\therefore \text{circle} = \pi r^2,$$

as was already proved in articles 54 and 55.

Or, since sectors have the same ratio as the arcs on which they stand (*Euclid* 33, vi.), if A = the angle of the sector, in degrees,

$$360° : A :: \text{area of circle} : \text{area of sector};$$

$$\therefore \text{sector} = \frac{A}{360} \pi r^2.$$

Mensuration.

Again, since $\frac{A}{360}=\frac{a}{2\pi r}$ (art. 48),

$$\text{the sector}=\tfrac{1}{2}ar;$$

and, finally, since $\theta=\frac{a}{r}$,

$$\text{the sector}=\tfrac{1}{2}\theta r^2.$$

We have therefore the following rules:—

(i.) *The area of a sector is equal to the area of the whole circle, multiplied by the number of degrees in the arc of the sector, and divided by* 360.

Example.—The radius of a sector is 25 feet, and its angle 68° 45′ 17″·8. Required its area.

Here $r=25$, $A=68·75494$;

$$\therefore \text{area of sector}=\frac{(25)^2\times 3·14159\times 68·75494}{360}=375 \text{ sq. ft.}$$

Or, by logarithms,

$\log r=1·3979400$
2
$2·7958800$
$\log \pi=\ ·4971499$
$\log A=1·8373039$
$\text{colog } 360=7·4436975$
$\log \text{area}=2·5740313$

Area $=375$.

Since, by art. 63, a sector

$$=\frac{A}{360}\pi r^2=\tfrac{1}{2}\times\frac{A\pi}{180}\times r^2;$$

where $\frac{A\pi}{180}=$ the length an arc of A° to radius 1, its area will be found by ascertaining the value of $\frac{A\pi}{180}$ from Table IV., and multiplying by the square of the radius.

Example.—To find the sector whose radius is 25 and angle 68° 45′ 17″·8.

From Table II. (see art. 51).—The length of an arc of 68° 45′ 17″·8 to radius $1=1·2$;

$$\therefore \text{area of sector}=1·2\times(25)^2=1·2\times 625=375.$$

(ii.) *The area of a sector is equal to one-half of the length of its arc multiplied by its radius.*

Example.—If the radius of a sector be 25 feet, and the length of its arc 30 feet,

$$\text{its area}=\tfrac{1}{2}\times 30\times 25=375 \text{ square feet.}$$

(iii.) If the radius AC and chord AB (fig. art. 22) be given, putting $AC=r$, $AB=2c$,

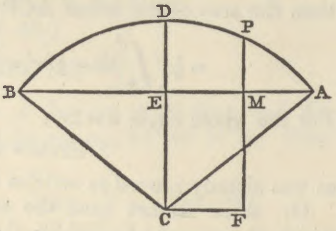
$$\text{we have } \sin\frac{A}{2}=\frac{c}{r},$$

whence A is known; and the area of the sector is found by Rule (i.)

Example.—If the radius of a sector is 25, and the chord of its arc 28·23214, what is its area?

Here A is ascertained to be 68° 45′ 17″·8 (see art. 52); and by Rule (i.) the area of the sector is found to be 375.

60. *To find the Area of a Segment of a Circle.*—Let C be the centre of the circle, $CD=r$, $DE=a$, $MP=b$, $CE=c$, $EM=h$, $AE=l$. Then, if $EM=x$, and $MP=y$,



$$(y+c)^2+x^2=r^2,$$

and the area DEMP

$$=\int_0^h y\,dx=\int_0^h (r^2-h^2)^{\frac{1}{2}}dx,$$

$$=\frac{r^2}{2}\sin^{-1}\frac{h}{r}+\frac{h}{2}(r^2-h^2)^{\frac{1}{2}}-ch.$$

Also the area $ADB=\int_{-l}^{+l} y\,dx$

$$=r^2\sin^{-1}\frac{l}{r}-cl=\text{sector } ACBD-\text{triangle } ABC.$$

Mensuration.

61. We may also express the areas DEMP, ADBE, in terms of AE, DE, and MP.

For, from the equation to the circle,

$$(b+c)^2+h^2=r^2\ (a+c)^2.$$

Whence $c=\frac{b^2+h^2-a^2}{2(a-b)}$, $r=\frac{(a-b)^2+h^2}{2(a-b)}$, and $(r^2-h^2)^{\frac{1}{2}}$

$$=b+c=\frac{h^2-(a-b)^2}{2(a-b)}.$$

Wherefore, substituting area DEMP

$$=\frac{1}{4(a-b)}\left\{\frac{[(a-b)^2+h^2]^2}{2(a-b)}\sin^{-1}\frac{2(a-b)h}{(a-b)^2+h^2}+(a^2+2ab-3b^2-h^2)h\right\}.$$

When $h=l$, $b=o$;

$$\therefore \text{area } ABD=\frac{1}{2a}\left\{\frac{(a^2+l^2)^2}{2a}\sin^{-1}\frac{2al}{a^2+l^2}-(l^2-a^2)\,l\right\}.$$

62. Again, since the area of the segment $ADB=$ sector $ADBC-$ triangle ABC; putting angle $ACB=\theta$, and $AC=r$,

$$\text{the segment}=\tfrac{1}{2}\theta r^2-\tfrac{1}{2}r^2\sin\theta \quad \text{(arts. 59 and 11)}$$
$$=\tfrac{1}{2}r^2(\theta-\sin\theta).$$

Whence (i.) *to find the area of a segment of a circle, find the area of the corresponding sector, and subtract the triangle contained by the radii of the sector and the base of the segment.*

Among various particular cases of this problem, the following may be noted:—

(ii.) *Given the radius* $AC=r$, *and the angle at the centre* $ACB=A°$.

$$\text{The sector } ADBC=\frac{A}{360}\pi r^2 \text{ (art. 59)};$$

$$\text{the triangle } ABC=\tfrac{1}{2}r^2\sin A;$$

$$\therefore \text{area of segment } ABD=\tfrac{1}{2}r^2\left(\frac{\pi A}{180}-\sin A.\right)$$

Example.—Find the area of the segment whose arc has a radius of 25 feet, and which subtends an angle of 68° 45′ 17″·8 at the centre.

$r=25$ $\log r=1·3979400$
2
$\log r^2=2·7958800$
$A=68°45'17''·8$ $L\sin A=9·9694343$
$\text{colog } 2=9·6989700$
$2·4642843$

Area of triangle 291·262.

In *Ex.* Rule (i.) (art. 59), the area of the sector has been found to be $=375·000$
the triangle $=291·262$
$\therefore$ segment $=\ 83·738$

(iii.) *Given the Chord and Radius of the Segment.*—Let $2c=$ the chord, $r=$ the radius, $A=$ angle at centre.

$$\text{Then } \sin\frac{A}{2}=\frac{c}{r};$$

and A being known, the area of the segment is found by Rule (ii.)

Example.—Find the area of the segment whose radius is 25, and chord 28·23214.

$c=14·11607$, from which $A=68°\ 45'\ 17''·8$ (see *Ex.* art. 52); and the area is then found, by Rule (ii.), to be 83·738.

(iv.) *Given the chord and height, or versed sine of the segment.*—Let $2c=$ the chord, $h=$ the height, $r=$ the radius.

$$r=\tfrac{1}{2}\left(h+\frac{c^2}{h}\right) \text{ (art. 53).}$$

Then A is found as in Rule (iii.), and finally the area is obtained by Rule (ii.)

Example.—Given the chord of a segment 28·23214, and its height 4·36661, to find its area.

$c=14·11607$ and $h=4·36661$, from which $r=25$ (see art. 53).

From r and c we have

$$A = 68° \ 45' \ 17''{\cdot}8 \text{ by Rule (iii.).}$$

Finally, from r and A we find by Rule (ii.) that

$$\text{the area } = 83{\cdot}738.$$

(v.) *Given the height and radius or diameter of the segment.*—Let $r =$ the radius, $h =$ the height, then, by (ii.),

$$\text{the area } = \tfrac{1}{2}\left(\frac{\pi A}{180} - \sin A\right) \times r^2;$$

and we have

$$\text{versin } A = \frac{h}{r}.$$

Whence A is known, and the area may be calculated as in (ii.).

If the radius be divided into n equal parts, and h be taken successively equal to $\frac{r}{n}$, $\frac{2r}{n}$, &c., the corresponding values of $\frac{h}{r}$, and of the factor $\tfrac{1}{2}\left(\frac{\pi A}{180} - \sin A\right)$ may be calculated and arranged in a table (see Table V.). *The area of any segment may then be ascertained by dividing its height by the radius of its arc, so as to obtain the tabular versed sine and the corresponding tabular number, and then multiplying the tabular number by the square of the radius of the segment.*

Example.—To find the area of a segment whose height is 4·36661, and whose radius is 25.

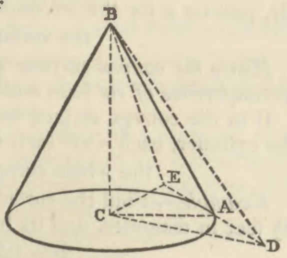
$$\text{Here } h = 4{\cdot}36661, \ d = 50.$$

$$\text{Tabular versin} = \frac{h}{r} = \frac{4{\cdot}36661}{25} = {\cdot}175 \text{ nearly.}$$

The tabular number for ·175, obtained by taking the mean of those for ·17 and ·18, is ·134396;

$$\therefore \text{ area of segment} = {\cdot}134396 \times (25)^2 = 84 \text{ nearly.}$$

The Cone.



63. *To find the Volume of a Right Cone.*—The right cone is generated by the revolution of a right-angled triangle ABC about its side BC.

Let BED be the side of a regular pyramid of n sides described about the cone, and put $AC = r$, $BC = h$.

Then the volume of the pyramid (art. 36)

$$= \tfrac{1}{3}n \cdot \text{CED} \cdot \text{BC} = \tfrac{1}{3}n \cdot \text{AC} \cdot \text{AD} \cdot \text{BC}$$

$$= \tfrac{1}{3}nr^2h \tan\frac{\pi}{n} = \tfrac{1}{3}\pi r^2 h \cdot \frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}.$$

But by increasing n indefinitely,

$$\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}} = 1 \text{ ultimately,}$$

and the pyramid becomes ultimately equal to the cone. Therefore the volume of the cone

$$= \pi r^2 h, \text{ or } = \tfrac{1}{3}m^2 h;$$

where m^2 is put for the area of the base of the cone.

Hence the volume of a cone is equal to one-third the product of the area of its base multiplied by its height.

Example.—Find the volume of the cone whose height is 13, and the radius of its base 3·5.

The area of the base $= 38{\cdot}4845$ (*Ex.* (i.) art. 56);

Therefore the volume $= \tfrac{1}{3} \times 13 \times 38{\cdot}4845 = 166{\cdot}77$.

64. *To find the Surface of a Right Cone.*—Putting $AB = l$, the lateral surface of the pyramid described about the cone,

$$= n\,\text{BED} = n\,\text{AB} \cdot \text{AD} = nlr \tan\frac{\pi}{n} = \pi lr \cdot \frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}.$$

But by increasing n indefinitely,

$$\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}} = 1;$$

and the surface of the pyramid coincides with that of the cone;

$$\therefore \text{ surface of cone } = \pi lr.$$

Also, if $p =$ the circumference of the base,

$$\therefore \pi lr = \tfrac{1}{2} \cdot 2\pi r \cdot l = \tfrac{1}{2}pl;$$

$$\therefore \text{ the convex surface } = \tfrac{1}{2}pl.$$

Hence the convex surface of a cone is equal to half the perimeter of the base multiplied by the slant height.

If we add the surface of the base, the whole surface,

$$= \pi r^2 + \pi lr$$

$$= \pi r(r + l).$$

Again, if $h =$ the vertical height,

$$l = (r^2 + h^2)^{\frac{1}{2}}$$

$$\therefore \text{ surface } = \pi r\{r + (r^2 + h^2)^{\frac{1}{2}}\}.$$

Example.—Find the surface of a cone whose height is 13, and the radius of its base 3·5,

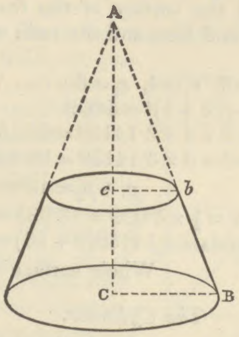
The slant height $l = (169 + 12{\cdot}25)^{\frac{1}{2}} = 13{\cdot}46$ nearly.

The convex surface $= 3{\cdot}14159 \times 3{\cdot}5 \times 13{\cdot}46 = 148{\cdot}0$

The surface of the base (art. 56) $= \ \ 38{\cdot}5$

The whole surface $= 186{\cdot}5$

65. *To find the Volume of the Frustum of a right Cone.*—The frustum is cut off by a plane parallel to the base.



Let the radii of the ends $BC = r_1$, $bc = r_2$, and the height $Cc = h$. Also, let $AC = h_1$, $Ac = h_2$.

$$\text{Then } \frac{h_1}{h_2} = \frac{r_1}{r_2}; \ \therefore \frac{h_1}{h} = \frac{r_1}{r_1 - r_2}.$$

$$\text{From which } h_1 = \frac{r_1 h}{r_1 - r_2}, \text{ and } h_2 = \frac{r_2 h}{r_1 - r_2}.$$

Since the frustum = difference of cones ABC, Abc,

$$\text{its volume } = \tfrac{1}{3}\pi r_1^2 h_1 - \tfrac{1}{3}\pi r_2^2 h_2 \text{ (art. 63)}$$

$$= \tfrac{1}{3}\pi h \cdot \frac{r_1^3 - r_2^3}{r_1 - r_2} = \tfrac{1}{3}\pi h(r_1^2 + r_1 r_2 + r_2^2).$$

Or if a_1^2, a_2^2 be the areas of the ends of the frustum,

$$\text{the volume} = \tfrac{1}{3}h(a_1^2 + a_1 a_2 + a_2^2).$$

66. It may also be shown, as in art. 39, that the volume

$$= \tfrac{1}{6}h(a_1^2 + 4a_2^2 + a_3^2).$$

Where a_1^2, a_3^2 are the areas of the terminating planes of the frustum, and a_2^2 the area of a section parallel to these planes, and equidistant from them.

Example.—Find the volume of the frustum of a cone, the radii of whose ends are 3 and 4 feet, and its height 5 feet.

log 3 = ·4771213
2
log $(3)^2$ = ·9542425
log π = ·4971499
log a_2^2 = 1·4513924

log 4 = ·6020600
2
log $(4)^2$ = 1·2041200
·4971499
log a_1^2 = 1·7012699
log a_2^2 = 1·4513924
2) 3·1526623
log a_1a_2 = 1·5763312

$a_1^2=50·266$
$a_2^2=28·274$
$a_1^2=37·699$
116·639

log = 2·0653519
log 5 = ·6989700
colog 3 = 9·5228787
Volume = 193·73. log volume = 2·2872006

67. *To find the Surface of the Frustum of a Cone.*—If the slant heights (fig. art. 65) AB, Ab, Bb, be l_1, l_2, and l respectively, it may be shown, as in last article, that

$$l_1=\frac{lr_1}{r_1-r_2},\text{ and } l_2=\frac{lr_2}{r_1-r_2};$$

and since the lateral surface of the frustum is equal to the difference of the lateral surfaces of the cones;

$$\therefore\text{ lateral surface}=\pi l_1r_1-\pi l_2r_2\text{ (art. 64)};$$

$$=\pi l\cdot\frac{r_1^{\,2}-r_2^{\,2}}{r_1-r_2}=\pi l(r_1+r_2).$$

Again, because the surface

$$=\tfrac{1}{2}l(2\pi r_1+2\pi r_2),$$

if p_1, p_2 be put for the perimeters of the ends,

$$\text{the lateral surface }=\tfrac{1}{2}l(p_1+p_2).$$

The whole surface is obtained by adding to the lateral surface the areas of the circles which form the ends of the frustum.

If the perpendicular height h be given, we have evidently

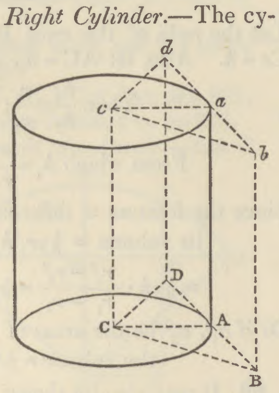
$$l=\{h+(r_1-r\quad\}^{\frac{1}{2}}.$$

Example.—Find the surface of the frustum of a right cone whose height is 5 feet, and the radii of its ends 3 and 4 feet.

Here $h=5$, $r_1=4$, $r_2=3$;
$\therefore l=(25+1)^{\frac{1}{2}}=5·099$
$p_1=2\times4\times3·14159=25·133$
$p_2=2\times3\times3·14159=18·850$
$p_1+p_2=43·983$
Convex surface $=\frac{1}{2}\times5·099\times43·983=112·13$
The areas of ends $=3·14159(9+16)=$ 78·54 (art. 56)
Whole surface = 190·67

The Cylinder.

68. *To find the Volume of a Right Cylinder.*—The cylinder is generated by the revolution of a rectangle ACca about its side Cc.



Let BDdb be the side of an equilateral prism of n sides described about the cylinder, and put AC $=r$. Then the base of the prism is a regular polygon of n sides whose area

$$=nr^2\tan\frac{\pi}{n}\text{ (art. 25.)}$$

Therefore the volume of the prism

$$=nr^2h\tan\frac{\pi}{n}=\pi r^2h\cdot\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}.$$

But when n is increased indefinitely, the prism evidently coincides with the cylinder,

$$\text{and }\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}=1;$$

$$\therefore\text{ the cylinder }=\pi r^2h.$$

Or if m^2 be put for the area of the base,

$$\text{the cylinder}=m^2h.$$

Hence the volume of a cylinder is equal to the area of its base multiplied by its height.

Example.—Find the volume of a cylinder whose base is $4\frac{1}{2}$ feet in diameter and its height 8 feet.

Here $r=2·25$, $h=8$.
log 2·25 = ·3521825
2
log $(2·25)^2$ = ·7043650
log π = ·4971499
log 8 = ·9030900
Volume = 127·235. log volume = 2·1046049

69. *To find the Surface of a Cylinder.*—The lateral surface of the prism in last article $=n\times$ parallelogram Bd,

$$=2n\cdot\text{AB}\cdot\text{A}a=2nhr\tan\frac{\pi}{n}=2\pi hr\cdot\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}.$$

But by indefinitely increasing n, the surface of the prism will coincide with that of the cylinder, and ultimately

$$\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}=1;$$

$$\therefore\text{ convex surface of cylinder}=2\pi rh.$$

Or, putting p for the circumference of the base,

$$\text{the surface}=ph.$$

Hence the convex surface of a cylinder is equal to the circumference of its base multiplied by its height.

If to the convex surface we add the areas of the ends of the cylinder, each $=\pi r^2$ (art. 55), we obtain

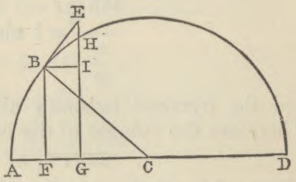
$$\text{the whole surface}=2\pi r(r+h).$$

Example.—Find the surface of a cylinder whose base is $4\frac{1}{2}$ feet in diameter, and its height is 8 feet.

$2r=4·5$, $h=8$.
log 4·5 = ·6532125   By art. 55,
log 8 = ·9030900   surface of ends = 31·808.
log π = ·4971499   convex surface = 113·098.
Log convex surface = 2·0534524   whole surface = 144·906.

The Sphere.

70. *To find the Surface of a Sphere or of a Spherical Segment or Zone.*—Let the sphere be generated by the revolution of the semicircle ABD round AD; and put AC $=r$, AF $=x$, BF $=y$. Then



$$y^2=2rx-x^2,\ \frac{dy}{dx}=\frac{r-x}{y};$$

and the surface generated by the revolution of the arc AB

$$=2\pi\int_0^x y\left(1+\frac{dy^2}{dx}\right)^{\frac{1}{2}}dx=2\pi\int_0^x rdx=2\pi rx.$$

Hence the convex surface of a segment whose height is h $=2\pi rh$.

Also, if AG $=a$, AF $=b$, FG $=h$, the surface of the zone generated by BH

$$=2\pi\int_b^a r\,dx=2\pi r(a-b)=2\pi rh:$$

and, if AD $=d$, the surface of the whole sphere

$$=2\pi\int_0^{2r} r\,dx=4\pi r^2=\pi d^2.$$

71. Otherwise: let BE be a tangent to the circle. Then if the figure revolves about AD, BH will describe a spherical, and BE a conical surface; and if EG be taken indefinitely near to BF, the two surfaces will ultimately be equal.

Let AC $=r$, and ACB $=\theta$.
Then BF $=r\sin\theta$, and BE $=$ FG $\operatorname{cosec}\theta$.

Also the conical surface

$$\begin{aligned}&=\pi\cdot \mathrm{BE}\,(\mathrm{BF}+\mathrm{EG})\ \text{(art. 67)}\\&=2\pi\cdot\mathrm{BF}\cdot\mathrm{BE},\ \text{ultimately},\\&=2\pi r\sin\theta\cdot\mathrm{FG}\operatorname{cosec}\theta\\&=2\pi r\cdot\mathrm{FG}.\end{aligned}$$

Now, as this value is independent of θ, and is ultimately the surface of the elementary zone generated by BH; it is evident that the surface of any segment or zone is equal to $2\pi r$ multiplied by the sum of the heights of the elementary zones of which it is composed. Hence if AG $=h$, the surface of the segment generated by ABH $=2\pi rh$: or if FG $=h$, the surface of the zone generated by BH $=2\pi rh$.

Also, the surface of the sphere is obviously

$$=2\pi r\times 2r=4\pi r^2.$$

72. (i.) *Hence the surface of a sphere is equal to four times the area of its great circle, or of a section by a plane passing through its centre.*

Example.—To find the surface of a sphere whose diameter is 7.

The surface of the circle whose diameter is 7 has been found (*Ex.* (ii.), art. 65) to be 38·4845.

Therefore the surface of the sphere $=4\times 38{\cdot}4845=153{\cdot}938$.

(ii.) *The convex surface of a segment, or zone of a sphere, is equal to the circumference of a great circle multiplied by the height of the segment or zone.*

Example.—Find the convex surface of a segment or of a zone whose height is 3, the diameter of the sphere being 5. The circumference of the circle whose diameter is 5 has been found (*Ex.* (i.), art. 45) to be 15·70796.

Therefore the surface of the segment or of the zone

$$=3\times 15{\cdot}70796=47{\cdot}12388.$$

73. *To find the Surface of a Lune, a Spherical Triangle, and a Spherical Polygon.*—It will be shown in spherical trigonometry—

(i.) That the area of a lune included between two great circles of a sphere whose inclination is θ,

$=2\theta r^2$; where r is the radius of the sphere;

(ii.) That the area of a spherical triangle whose angles are A, B, and C, $=r^2(\mathrm{A}+\mathrm{B}+\mathrm{C}-\pi)$; and

(iii.) That the area of a spherical polygon of n sides, the sum of whose angles is P, is

$$r^2\,\{\mathrm{P}-(n-2)\pi\}.$$

74. *To find the Volume of a Sphere.*—If we retain the figure and notation of art. 70, the volume of the segment generated by the revolution of the figure ABF,

$$=\pi\int_0^x y^2dx=\pi\int_0^x(2rx-x^2)\,dx=\frac{\pi x^2}{3}\,(3r-x).$$

Also the volume of the whole sphere

$$=\pi\int_0^{2r} y^2\,dx=\frac{4}{3}\pi r^3.$$

75. Or, if we suppose a regular polyhedron of n faces described about the sphere, by indefinitely increasing n, the surface and volume of the polyhedron will be ultimately equal respectively to the surface and volume of the sphere.

Now, if a^2 be put for one of the faces of the polyhedron, its volume is equal to n pyramids, whose bases are each a^2, and their common height the radius of the sphere.

Therefore the volume of the polyhedron

$$\begin{aligned}&=n\times\tfrac{1}{3}a^2r=\tfrac{1}{3}r\times na^2,\\&=\tfrac{1}{3}r\times\ \text{surface of polyhedron},\\&=\tfrac{1}{3}r\times\ \text{surface of sphere, ultimately},\\&=\tfrac{1}{3}r\times 4\pi r^2.\end{aligned}$$

Whence the volume of the sphere $=\frac{4}{3}\pi r^3$.

From this it follows that if d be the diameter of the sphere,

$$\text{the volume}=\tfrac{1}{6}\pi d^3.$$

$\therefore$ Since $\frac{4}{3}\pi=4{\cdot}1887902048$, and $\frac{1}{6}\pi={\cdot}5235987756$; *to find the volume of a sphere, multiply the cube of the radius by* 4·1887902, *or the cube of the diameter by* ·5235988.

Example.—Find the volume of a sphere whose radius is 12.

$$\begin{aligned}\text{The volume}=(12)^3\times\tfrac{4}{3}\pi&=1728\times 4{\cdot}1887902\\&=7238{\cdot}2295.\end{aligned}$$

76. It obviously follows from arts. 70 and 74 that in a sphere

$$\text{radius}=\frac{1}{2\sqrt{\pi}}\cdot\sqrt{(\text{surface})}=\sqrt[3]{\frac{3}{4\pi}}\cdot\sqrt[3]{(\text{volume})};$$

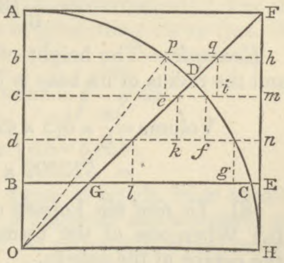
$$\text{diameter}=\frac{1}{\sqrt{\pi}}\cdot\sqrt{(\text{surface})}=\sqrt[3]{\frac{6}{\pi}}\cdot\sqrt[3]{(\text{volume})};$$

$$\text{surface}=\sqrt[3]{}\cdot\pi\sqrt[3]{(6\,\text{volume})^2};\ \text{volume}=\frac{1}{6\sqrt{\pi}}\cdot\sqrt{(\text{surface})^3}.$$

77. *To find the Volume of the Segment of a Sphere.*—The volume of a segment whose height is h

$$=\pi\int_0^h y^2dx=\pi\int_0^h(2rx-x^2)\,dx=\frac{\pi h^2}{3}\,(3r-h).$$

78. The same result may be obtained by supposing the parallelogram ABEF, the quadrilateral ABGF, and the segment ABCD, to revolve about AB so as to generate a cylinder, a frustum of a cone, and a segment of a sphere. If AB be divided into equal parts, Ab, bc, &c., each $=c$, and the rectangles be, bi, ch, cf, &c., be constructed, these rectangles will generate cylinders; and by indefinitely increasing the number of parts into which AB is divided, the sum of the cylinders generated by be, cf, &c., will ultimately be equal to the segment of the sphere generated by ABCD, and the sum of the cylinders generated by Ah, bi, &c., will ultimately be equal to the frustum of the cone generated by ABGF; while the cylinders generated by Ah, bm, &c., constitute the cylinder generated by ABEF.



$$\text{Now } bh^2=\mathrm{O}p^2=bp^2+\mathrm{O}b^2=bp^2+bq^2;$$

$$\therefore\ \pi c\cdot bh^2=\pi c\cdot bp^2+\pi c\cdot bq^2:$$

or the cylinder generated by bm is equal to the sum of those generated by be and bi; and because this is true of every corresponding set of cylinders, we have,

Sum of cylinders generated by Ah, bm, &c. $=$ sum of cylinders generated by be, cf, &c. $+$ sum of cylinders generated by Ah, bi, &c.

Therefore since these sums are ultimately equal respectively to the cylinder generated by ABEF, the sphere generated by ABCD, and the conic frustum generated by ABGF, we have

Cylinder $=$ segment of sphere $+$ frustum of cone.

Mensuration.

Now, if AF $=r$ and AB $=h$, we have

$$Bg=r-h\,;$$

therefore (art. 65) the frustum of the cone

$$=\frac{\pi h}{3}(3r^2-3rh+h^2).$$

Also, the cylinder (art. 68) $=\pi r^2h$; therefore the segment of the sphere

$$=\pi r^2h-\frac{\pi h}{3}(3r^2-3rh+h^2)$$

$$=\frac{\pi h^2}{3}(3r-h).$$

If we put $h=2r$, we obtain the volume of the whole sphere $=\frac{4}{3}\pi r^3$, as in art. 74.

Example.—Find the volume of the segment of a sphere; the radius being 12, and the height of the segment 6.

$$\text{The volume}=\frac{\pi}{3}\times 36\,(36-6)=3{\cdot}14159\times 360$$

$$=1130{\cdot}9733552.$$

79. It is evident that we may prove, in like manner, that the cylinder generated by AOHF is equal to the sum of the hemisphere and cone generated by ADHO and AOF. Whence it easily follows (arts. 63, 68), that if we have a cone and sphere inscribed in a cylinder,

the cylinder = sphere + cone = sphere + $\frac{1}{3}$ cylinder;

$\therefore$ the sphere = $\frac{2}{3}$ cylinder, and

cone : sphere : cylinder : : 1 : 2 : 3;

a relation also obviously true from their ascertained volumes, which are respectively $\frac{2}{3}\pi r^3$, $\frac{4}{3}\pi r^3$, and $2\pi r^3$.

80. Since, from the equation to the circle, $y^2=2rx-x^2$; putting a for the radius BC of the base of the segment generated by ABCD, we have

$$a^2=2rh-h^2\,;\quad \therefore\ r=\frac{a^2+h^2}{2h}.$$

Whence, substituting, we obtain the segment of a sphere, whose height is h, and the radius of its base a,

$$=\frac{\pi h}{6}(3a^2+h^2).$$

Example.—The height of a segment of a sphere is 5, and the radius of its base is 7.

$$\text{Volume}=\frac{\pi}{6}\times 5(3\times 49+25)$$

$$=\cdot 523599\times 860=450{\cdot}29.$$

81. *To find the Volume of the Frustum of a Sphere*—(i.) When one of the terminating planes passes through the centre of the sphere.

Let BO $=l$, then AB or $h=r-l$; and the frustum generated by the revolution of BCHO = hemisphere generated by AOH − spherical segment generated by ABCD,

$$=\frac{2}{3}\pi r^3-\frac{\pi}{3}(r-l)^2\,(2r+l)=\frac{\pi l}{3}(3r^2-l^2).$$

Example.—Find the volume of the frustum of a sphere; the radius of the sphere being 12, the height of the frustum 6, and one of its terminating planes passing through the centre.

$$\text{The volume}=\frac{\pi}{3}\times 6\,(3\times 144-36)$$

$$=3{\cdot}14159\times 792$$

$$=2488{\cdot}1413816.$$

(ii.) When neither of the terminating planes passes through the centre.

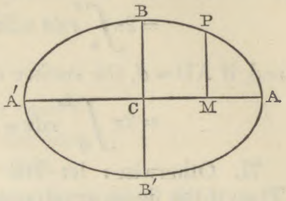
If h be the height of the frustum, and a_1, a_2 the radii of its ends,

$$\text{the volume}=\frac{\pi h}{6}\{3\,(a_1{}^2+a_2{}^2)+h^2\}.$$

Mensuration.

SECTION IV.—THE ELLIPSE.

82. *To find the Length of an Arc of an Ellipse.*—If AC $=a$, BC $=b$, CM $=x$, and MP $=y$, the equation to the ellipse is



$$a^2y^2+b^2x^2=a^2b^2\,;$$

$$\text{whence }\frac{dy}{dx}=-\frac{b^2x}{a^2y}.$$

The length of an arc BP

$$=\int_0^x\left(1+\frac{dy^2}{dx^2}\right)^{\frac{1}{2}}dx=\int_0^x\left(\frac{a^2-e^2x^2}{a^2-x^2}\right)^{\frac{1}{2}}dx,$$

$$\text{where } e^2=\frac{a^2-b^2}{a^2}.$$

Putting $x=az$,

$$\text{the arc BP}=a\int\frac{(1-e^2z^2)^{\frac{1}{2}}}{(1-\ z^2\,)^{\frac{1}{2}}}\,dz$$

$$=a\int\frac{dz}{(1-z^2)^{\frac{1}{2}}}\left\{1-\frac{1}{2}e^2z^2-\frac{1\cdot 1}{2\cdot 4}e^4z^4-\frac{1\cdot 1\cdot 3}{2\cdot 4\cdot 6}e^6z^6+\&c.\right\}$$

To obtain the length of a quadrant of the ellipse, we must integrate from $x=0$ to $x=a$, or from $z=0$ to $z=1$; when we obtain (see FLUXIONS)

$$\text{the quadrant APB}=\frac{\pi a}{2}\left\{1-\frac{e^2}{2^2}-\frac{1\cdot 3e^4}{2^2\cdot 4^2}-\frac{1\cdot 3^2\cdot 5e^6}{2^2\cdot 4^2\cdot 6^2}-\&c.\right\}:$$

a rapidly converging series when e is small.

83. We shall obtain more and more accurate values of the circumference of the ellipse according to the number of terms of the above series we employ. The following is the first approximation:—

$$\text{Since }(1-\tfrac{1}{2}e^2)^{\frac{1}{2}}=1-\frac{e^2}{2^2}+\&c.,$$

we have the elliptic quadrant $=\frac{\pi a}{2}(1-\frac{1}{2}e^2)^{\frac{1}{2}}$ nearly

$$=\frac{\pi}{2}\,a\left(1-\frac{a^2-b^2}{2a^2}\right)^{\frac{1}{2}}=\frac{\pi}{2}\left(\frac{a^2+b^2}{2}\right)^{\frac{1}{2}}:$$

and the circumference of the ellipse

$$=\pi\left\{\frac{(2a)^2+(2b)^2}{2}\right\}^{\frac{1}{2}}\text{ nearly.}$$

Hence the circumference of an ellipse is obtained approximately by multiplying the square root of half the sum of the squares of its axes by 3·14159.

Example.—Find the circumference of an ellipse whose axes are 3 and 4.

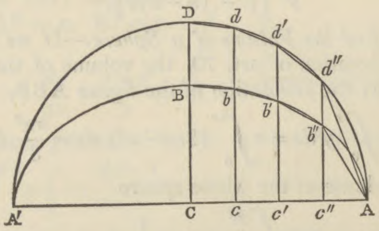
$$\text{The circumference}=3{\cdot}1416\left(\frac{9+16}{2}\right)^{\frac{1}{2}}$$

$$=\frac{3{\cdot}1416\times 5\sqrt{2}}{2}=11{\cdot}1\text{ nearly.}$$

84. *To find the Area of an Ellipse.*—The area of a quadrant ACB (fig. art. 82)

$$=\int_0^a ydx=\frac{b}{a}\int_0^a(a^2-x^2)^{\frac{1}{2}}dx=\frac{\pi ab}{4}.$$

85. Or if the ellipse ABA′ and the circle ADA be divided by lines cd, $c'd'$, &c., indefinitely near to each other, and parallel to CD, the polygons ACDd'', ACBb'', will be



ultimately equal to the circular and elliptic quadrants, in which they are inscribed; and if AC = a, BC = b,

$bc : cd :: b'c' :: c'd' :: b : a$. (ANAL. GEOM., art. 92, p. 553.)

Therefore the trapezoid $bcc'b'$ is to $dcc'd'$ in the same ratio (art. 14); and hence also the polygon ACBb'' is to the polygon ACDd'' in the same ratio of a to b.

Therefore, since the polygons are ultimately equal to the elliptic and circular quadrants, and the latter $= \frac{1}{4}\pi a^2$, we have

$$a : b :: \tfrac{1}{4}\pi a^2 : \text{elliptic quadrant ABC}.$$

$$\text{Whence the elliptic quadrant} = \tfrac{1}{4}\pi ab;$$
$$\text{and the ellipse} = \pi ab.$$

As this is the same as $\frac{1}{4}\pi \times 2a \times 2b$, *the area of an ellipse is equal to the product of the major and minor axes multiplied by* ·78539.

Example.—Find the area of an ellipse whose axes are 3 and 4.

$$\text{Area} = 3 \times 4 \times {\cdot}78539 = 80{\cdot}110613.$$

Spheroids.

86. *To find the Surface of a Prolate Spheroid.*—The prolate spheroid is generated by the revolution of an ellipse (fig. art. 82) about its major axis AA′, and the equation to the generating curve is therefore

$$a^2y^2 + b^2x^2 = a^2b^2.$$

$$\text{Whence } \frac{dy}{dx} = -\frac{b^2x}{a^2y}; \text{ and if } e^2 = \frac{a^2-b^2}{a^2},$$

$$y\left(1 + \frac{dy^2}{dx^2}\right)^{\frac{1}{2}} = \frac{b}{a}\left(a^2 - e^2x^2\right)^{\frac{1}{2}}.$$

Therefore, putting CM = h, the convex surface of the frustum of the spheroid generated by the figure BCMP

$$= 2\pi\int_0^h y\left(1+\frac{dy^2}{dx^2}\right)^{\frac{1}{2}} = \frac{2\pi b}{a}\int_0^h (a^2 - e^2x^2)^{\frac{1}{2}}$$

$$= \frac{\pi ab}{e}\left\{\sin^{-1}\frac{eh}{a} + \frac{eh}{a}\left(1 - \frac{e^2h^2}{a^2}\right)^{\frac{1}{2}}\right\}.$$

87. To obtain the surface of the whole spheroid, we must integrate from $x = -a$, to $x = a$, when we obtain

$$\text{surface of spheroid} = \frac{2\pi ab}{e}\{\sin^{-1}e + e(1-e^2)^{\frac{1}{2}}\}$$

$$= 2\pi a^2\{1 - e^2 + \frac{(1-e^2)^{\frac{1}{2}}}{e}\cdot\sin^{-1}e\}.$$

Example.—Find the surface of a prolate spheroid whose axes are 5 and 3.

$$\text{Here } a = \frac{5}{2},\ b = \frac{3}{2};$$

$$\therefore e = \left(\frac{25-9}{25}\right)^{\frac{1}{2}} = \frac{4}{5}, \text{ and } 1 - e^2 = \frac{9}{25}.$$

$$\text{Hence the surface} = 2\pi\left(\frac{5}{2}\right)^2\left\{\frac{9}{25} + \frac{3}{5}\cdot\frac{5}{4}\sin^{-1}\frac{4}{5}\right\}$$

$$= 12{\cdot}5\pi\{{\cdot}36 + {\cdot}75\sin^{-1}0{\cdot}8\}$$

$$\text{Now } \log 0{\cdot}8 + 10 = 9{\cdot}90309 = \text{L}\sin 53°\ 7'\ 49''$$
$$= \text{L}\sin 53°{\cdot}130 \text{ nearly};$$

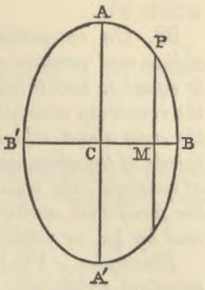
therefore (art. 51)

$$\sin^{-1}0{\cdot}8 = \frac{\pi}{180}\times 53{\cdot}130 = {\cdot}69547,$$

and the surface of the spheroid

$$= 3{\cdot}14159 \times 12{\cdot}5\,({\cdot}36 + {\cdot}69547) = 41{\cdot}448.$$

88. *To find the Surface of an Oblate Spheroid.*—The oblate spheroid is generated by the revolution of an ellipse AA′ about its minor axis BB. Hence if CM = x, and MP = y, the equation to the generating curve will be $a^2x^2 + b^2y^2 = a^2b^2$;



$$\therefore \frac{dy}{dx} = -\frac{a^2x}{b^2y}, \text{ and } y\left(1+\frac{dy^2}{dx^2}\right)^{\frac{1}{2}}$$

$$= \frac{a^2e}{b^2}(c^2 + x^2)^{\frac{1}{2}};$$

$$\text{where } e^2 = \frac{a^2-b^2}{a^2}, \text{ and } c = \frac{b^2}{ae} = \frac{a}{e}(1-e^2).$$

If CM = h, the convex surface generated by the revolution of the figure ACMP

$$= 2\pi\int_0^h y\left(1+\frac{dy^2}{dx^2}\right)^{\frac{1}{2}} = \frac{2\pi a^2e}{b}\int_0^h (c^2+x^2)^{\frac{1}{2}}\,dx$$

$$= \frac{\pi a^2}{e}\left\{h(c^2+h^2)^{\frac{1}{2}} + c^2\log\frac{h + (c^2+h^2)^{\frac{1}{2}}}{c}\right\}.$$

89. By integrating from $x = -b$ to $x = b$, we obtain the surface of the spheroid

$$= 2\pi a^2\left\{1 + \frac{1-e^2}{2e}\log\left(\frac{1+e}{1-e}\right)\right\}.$$

Example.—Find the surface of an oblate spheroid whose axes are 5 and 3.

$$\text{Here } a = \frac{5}{2},\ b = \frac{3}{2};\ \therefore e = \frac{4}{5}.$$

$$\text{Surface} = 2\pi\left(\frac{5}{2}\right)^2\left\{1 + \frac{5}{8}\cdot\frac{9}{25}\log\frac{1+\frac{4}{5}}{1-\frac{4}{5}}\right\}$$

$$= 12{\cdot}5\pi\left(1 + \frac{9}{40}\log 9\right).$$

$$\text{But } \frac{9}{40}\log_e 9 = \frac{9}{40}\times 2{\cdot}1972246 = {\cdot}4943755;^*$$

$$\therefore \text{surface} = 12{\cdot}5 \times 3{\cdot}14159 \times 1{\cdot}4943755 = 58{\cdot}685.$$

90. *To find the Volume of a Spheroid.*—(i.) For the *prolate spheroid* the equation to generating curve (art. 86) is $a^2y^2 + b^2x^2 = a^2b^2$.

$$\text{Whence the volume } \pi\int_{-a}^{+a} y^2dx$$

$$= \frac{\pi b^2}{a^2}\int_{-a}^{+a}(a^2 - x^2)\,dx = \tfrac{4}{3}\pi ab^2.$$

91. Or if we conceive the figure of article 84 to revolve about AA′, so as to generate a spheroid and a sphere, we may conceive these solids to be ultimately equal to two series of elementary cylinders described by the rectangles, whose bases are BC, bc, &c., and CD, cd, &c., and whose common altitude is Cc = cc' = &c.

$$\text{Then, because BC}^2 : \text{CD}^2 :: (bc)^2 : (cd)^2 :: b^2 : a^2;$$

$$\therefore \pi(bc)^2\cdot cc' : \pi(cd)^2\cdot cc' :: b^2 : a^2.$$

Whence the corresponding pairs of elementary cylinders which constitute the sphere and spheroid are in the constant ratio of a^2 to b^2; and since the sphere $= \frac{4}{3}\pi a^3$;

$$\therefore a^2 : b^2 :: \tfrac{4}{3}\pi a^3 : \text{spheroid}.$$

Hence the spheroid $= \frac{4}{3}\pi ab^2$.

92. (ii.) For the *oblate spheroid* the equation to the generating curve is $a^2x^2 + b^2y^2 = a^2b^2$ (art. 88).

$$\text{Whence the volume} = \pi\int_{-b}^{+b} y^2dx$$

$$= \frac{\pi a^2}{b}\int_{-b}^{+b}(a^2 - x^2)\,dx = \tfrac{4}{3}\pi a^2b.$$

---

* To obtain the logarithm of any number to the base e, multiply its common logarithm to the base 10 by 2·3025850929. Thus $\log_e 9 = {\cdot}9542425 \times 2{\cdot}3025850929 = 2{\cdot}1972246$.

The same result may also be obtained by the method of article 91.

93. *On comparing the expressions for the volumes of oblate and prolate spheroids, it appears that either volume is equal to two-thirds the area of the circle generated by the revolving axis of the ellipse, multiplied by the length of the axis about which it revolves: or the spheroid is two-thirds of the circumscribing cylinder. Also, for both species of spheroid, the volume is equal to the continued product of the fixed axis, multiplied by the square of the revolving axis, and by* $\frac{1}{6}\pi$, *or* ·52359878.

Examples.—Find the volumes of an oblate and prolate spheroid whose axes are 20 and 12.

The volume of the oblate spheroid

$$=\tfrac{4}{3}\pi \times 100 \times 6 = 800\pi = 2513{\cdot}274.$$

The volume of the prolate spheroid

$$=\tfrac{4}{3}\pi \times 36 \times 10 = 480\pi = 1057{\cdot}962.$$

94. *To find the Volume of a Segment of a Spheroid.*

(i.) *The prolate spheroid.*—The segment is generated by the revolution of AMP about AM (fig. art. 82).

If A be the origin, and AA′ the axis of x, the equation to the ellipse is

$$y^2 = \frac{b^2}{a^2}(2ax - x^2);$$

and if AM$=h$, the volume of the segment

$$=\pi\int_0^h y^2 dx,$$

$$=\frac{\pi b^2}{a^2}\int_0^h (2ax - x^2)\,dx = \frac{\pi}{3}\cdot\frac{b^2h^2}{a^2}(3a - h).$$

Example.—Find the volume of the segment of a prolate spheroid, where the axes of the generating ellipse are 20 and 12, and the height of the segment 8.

Here $a=10$, $b=6$, $h=8$.

The volume

$$=\frac{\pi}{3}\cdot\frac{36\times 64}{100}(30-8) = 3{\cdot}14159 \times \frac{12\times 64\times 22}{100} = 530{\cdot}8034.$$

95. (ii.) *The oblate spheroid.*—The segment is generated by the revolution of BMP (fig. art. 88) about BM; where, if B be the origin and BB′ the axis of x, the equation to the ellipse is

$$y^2 = \frac{a^2}{b^2}(2bx - x^2);$$

and if BM$=h$, the volume of the segment

$$=\frac{\pi a^2}{b^2}\int_0^h (2bx - x^2)\,dx = \frac{\pi}{3}\cdot\frac{a^2h^2}{b^2}(3b - h).$$

Example.—Find the volume of a segment of an oblate spheroid, the axes being 20 and 12, and the height of the segment 2.

$$a=10,\ b=6,\ h=2;$$

and the volume$=\frac{\pi}{3}\cdot\frac{100\times 4}{36}(18-2) = 186{\cdot}1658.$

96. *To find the Volume of the Frustum of a Spheroid when one of the Terminating Planes passes through the Centre.*

(i.) *The prolate spheroid.*—The frustum is generated by the revolution of the figure BCMP (fig. art. 82) about CM; and if CM$=h$, the volume of the frustum

$$=\frac{\pi b^2}{a^2}\int_0^h (a^2 - x^2)\,dx = \frac{\pi}{3}\cdot\frac{b^2h}{a^2}(3a^2 - h^2).$$

If b, b' be the radii BC, PM of the terminating planes of the frustum, since from the equation to the ellipse

$$b^2h^2 + a^2b'^2 = a^2b^2;\ \therefore\ h^2 = \frac{a^2(b^2 - b'^2)}{b^2}.$$

Whence, by substitution, the volume of the frustum

$$=\frac{\pi}{3}h(2b^2 + b'^2).$$

Example.—Find the volume of the frustum of a prolate spheroid whose axes are 20 and 12, the height of the frustum being 2, and one of its ends passing through the centre of the spheroid.

$$a=10,\ b=6,\ h=2.$$

The volume$=\frac{\pi}{3}\cdot\frac{36\times 2}{100}(300-4) = 223{\cdot}1787.$

97. (ii.) *The oblate spheroid.*—Adopting the figure and notation of article 88, the frustum is generated by the revolution of ACMP about CM. The equation is

$$a^2x^2 + b^2y^2 = a^2b^2;$$

and if CM$=h$, the volume

$$=\frac{\pi a^2}{b^2}\int_0^h (b^2 - x^2)\,dx = \frac{\pi}{3}\cdot\frac{a^2h}{b^2}(3b^2 - h^2).$$

Also, if a, a' be the radii of the terminating planes, since from the equation to the ellipse

$$a^2h^2 + a'^2b^2 = a^2b^2,$$

if we substitute for h^2 we obtain the volume

$$=\frac{\pi}{3}h(2a^2 + a'^2).$$

Example.—Find the volume of the frustum of an oblate spheroid whose axes are 20 and 12, the height of the frustum being 4, and one of its ends passing through the centre of the spheroid.

$$a=10,\ b=6,\ c=4.$$

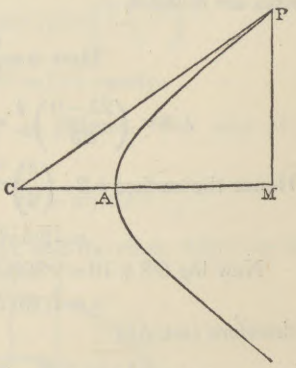
The volume$=\frac{\pi}{3}\cdot\frac{100\times 4}{36}(108-16) = 1070{\cdot}469.$

It appears also from the last two articles that the volume of a frustum, of either a prolate or oblate spheroid, one of whose ends passes through the centre of the generating ellipse, is obtained by adding the area of the smaller end to twice that of the greater, and multiplying the sum by one-third of the altitude of the frustum.

SECTION. V.—THE HYPERBOLA.

98. *To find the Area of an Hyperbola.*

(i.) The area of the segment AMP.



Let C be the centre, and CM the axis of x. The equation is

$$a^2y^2 - b^2x^2 = -a^2b^2;$$

and if CM$=h$, PM$=k$, the area AMP

$$=\int_a^h y\,dx = \frac{b}{a}\int_a^h (x^2 - a^2)^{\frac{1}{2}}$$

$$=\frac{b}{a}\left\{\frac{h}{2}(h^2 - a^2)^{\frac{1}{2}} - \frac{a^2}{2}\log\frac{h + (h^2 - a^2)^{\frac{1}{2}}}{a}\right\}$$

$$=\tfrac{1}{2}hk - \frac{ab}{2}\log\left(\frac{h}{a} + \frac{k}{b}\right);$$

where $b = \frac{ak}{(h^2 - a^2)^{\frac{1}{2}}}\cdot$

Example.—Find the area of a hyperbolic segment whose base is 48 and altitude 20; the transverse axis of the curve being 60.

$$a=30,\ k=24,\ \text{and}\ x=30+20=50;$$

$$\text{also } b=\frac{30\times 24}{(2500-900)^{\frac{1}{2}}}=\frac{720}{40}=18.$$

The area AMP

$$=\tfrac{1}{2}\times 50\times 24-\frac{30\times 18}{2}\log_e\left(\frac{50}{30}+\frac{24}{18}\right)$$

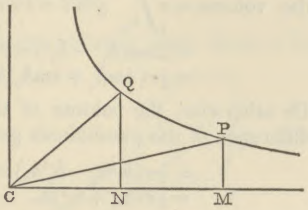
$$=600-270\log_e 3=600-270\times 1{\cdot}0986123\ \text{(note, art. 89)}$$
$$=303{\cdot}3756.$$

Hence the whole segment, which is double AMP,

$$=606{\cdot}7513.$$

99. (ii.) The area of the sector ACP.

$$\text{The area ACP}=\text{CMP}-\text{AMP}=\tfrac{1}{2}hk-\text{AMP}$$
$$=\frac{ab}{2}\log\left(\frac{h}{a}+\frac{k}{b}\right).$$



100. *To find the Area bounded by a Rectangular Hyperbola and its Asymptotes.*—The equation to the hyperbola referred to its asymptotes is

$$xy=\frac{a^2}{2}.$$

Let $\text{CM}=x_1$, $\text{CN}=x_2$, $\text{PM}=y_1$, $\text{QN}=y_2$.

$$\text{The area PMNQ}=\int_{x_2}^{x_1} y\,dx$$

$$=\frac{a}{2}\int_{x_2}^{x_1}\frac{dx}{x}=\frac{a^2}{2}\log\frac{x_1}{x_2}=\frac{a^2}{2}\log\frac{y_2}{y_1}.$$

From the equation:

$$\frac{x_1y_1}{2}=\frac{a^2}{4}=\frac{x_2y_2}{2},\ \text{or triangle CMP}=\text{triangle CNQ}.$$

Whence sector PCQ = area PMNQ.

101. If the ordinates $\text{PM}=k_1$, $\text{QN}=k_2$, and $\text{MN}=h$, be given, putting x_1, x_2 for CM, CN, as before,

$$x_1k_1=\frac{a^2}{2}=x_2k_2,\ \text{and}\ x_1-x_2=h.$$

$$\text{Whence}\ \frac{a^2}{2}=\frac{hk_1k_2}{k_2-k_1},$$

$$\text{and area PMNQ}=\frac{hk_1k_2}{k_2-k_1}\log\frac{k_2}{k_1}.$$

Example.—Given the ordinates PM = 20, QN = 45, and MN = 50, to find the area.

$$\text{Here}\ k_1=20,\ k_2=45,\ \text{and}\ h=50.$$

$$\text{The area}\ =\frac{50\times 20\times 45}{45-20}\log\frac{45}{20}$$

$$=1800\log\frac{9}{4}=1459{\cdot}67.$$

102. *To find the Volume of an Hyperboloid.*—The solid is generated by the revolution of the hyperbolic segment AMP about AM (fig. art. 98).

If, therefore, we put $\text{AM}=h$,

$$\text{the volume}=\pi\int_a^{a+h}y^2=\frac{\pi b^2}{a^2}\int_a^{a+h}(x^2-a^2)\,dx$$

$$=\frac{\pi b^2h^2}{3a^2}(3a+h).$$

103. If $\text{PM}=k$, from the equation to the hyperbola (art. 98),

$$ak^2-b^2(a+h)^2=-a^2b^2.$$

$$\text{Whence}\ \frac{b^2}{a^2}=\frac{k^2}{2ah+h^2}.$$

Therefore substituting, we obtain the volume of the hyperboloid,

$$=\frac{\pi hk^2}{3}\cdot\frac{3a+h}{2a+h}.$$

Example.—Find the volume of an hyperboloid, the radius of whose base is 24, its height 20, and the transverse axis of the generating curve 60.

$$\text{Here}\ a=30,\ k=24,\ h=20.$$

$$\text{The volume}\ =\frac{\pi\times 20\times(24)^2}{3}\cdot\frac{90+20}{60+20}$$
$$=5280\pi=16587{\cdot}6092.$$

104. The expression for the volume may be put into the form

$$\frac{\pi hk^2}{2}\cdot\frac{2a+\frac{2}{3}h}{2a+h},$$

whence the following rule:—*As the sum of the transverse axis of the generating hyperbola, and the height of the solid, is to the sum of the transverse axis and $\frac{2}{3}$ of the height, so is half the cylinder of the same base and altitude to the volume of the hyperboloid.*

105. *To find the Volume of the Solid generated by the Revolution of a Rectangular Hyperbola about its Asymptote.*

The solid is generated by the revolution of PMNQ (fig. art. 100) about MN.

If $\text{CM}=x_1$, $\text{CN}=x_2$, and $\text{MN}=h$,

$$\text{the volume}=\pi\int_{x_2}^{x_1}y^2dx=\frac{\pi a^4}{4}\int_{x_2}^{x_1}\frac{dx}{x^2}$$

$$=\frac{\pi a^4}{4}\left(\frac{1}{x_2}-\frac{1}{x_1}\right)=\frac{\pi a^4h}{x_1x_2}.$$

Now if r_1, r_2 be the radii PM, QN of the ends of the solid,

$$r_1x_1=r_2x_2=\frac{a^2}{2};$$

$$\text{therefore}\ x_1x_2=\frac{a^4}{4r_1r_2}.$$

$$\text{Whence the volume}=\pi r_1r_2h;$$

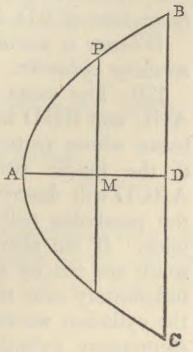
or the volume is equal to the continued product of the radii of its ends, its height, and 3·14159.

Example.—Find the volume of the hyperbolic solid generated by PMNQ, where PM = 20, QN = 45, and MN = 50.

$$\text{The volume}=20\times 45\times 50\times\pi$$
$$=141371{\cdot}669.$$

SECTION VI.—THE PARABOLA.

106. *To find the Length of an Arc of a Parabola.*—The equation to the parabola being $y^2=4mx$, the length of the arc AB, where $\text{AD}=h$,



$$=\int_0^h\left(1+\frac{dy^2}{dx^2}\right)^{\frac{1}{2}}dx$$

$$=\int_0^h\left(1+\frac{m}{x}\right)^{\frac{1}{2}}dx$$

$$=(mh+h^2)^{\frac{1}{2}}$$

$$+\frac{m}{2}\log\left\{\frac{m+2[h+(mh+h^2)^{\frac{1}{2}}]}{m}\right\}.$$

$$\text{If BD}=b,\ b^2=4mh;\ \therefore m=\frac{b^2}{4h}.$$

Whence the arc BAC

$$=(b^2+4h^2)^{\frac{1}{2}}+\frac{b^2}{4h}\log\left\{\frac{b^2+8[h^2+(b^2+4h^2)^{\frac{1}{2}}]}{b^2}\right\}.$$

Example.—If AD = 4, and BC = 12, then $b = 6$, and $h = 4$.

$$\text{The arc BAC} = 10 + \frac{9}{4}\log_e\frac{61}{9}$$

$$= 10 + \frac{9}{4} \times 1{\cdot}9236493 = 14{\cdot}3282.$$

107. *To find the Area of a Parabola.*—In the figure of last article the area ABD

$$= \int_0^x y\,dx = 2m^{\frac{1}{2}}\int_0^x x^{\frac{1}{2}}dx$$

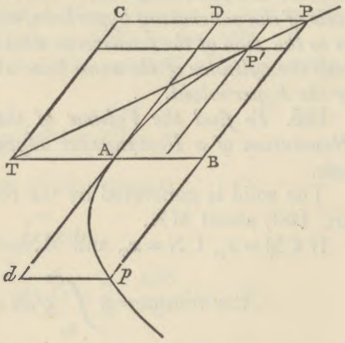
$$= \tfrac{4}{3}m^{\frac{1}{2}}x^{\frac{3}{2}} = \tfrac{2}{3}xy.$$

Or if AD $= h$, and BD $= b$,

$$\text{the area ABD} = \tfrac{2}{3}bh.$$

Whence the area ABC $= \tfrac{2}{3}$AD·BC.

108. Or if PT be a tangent to the parabola AP, AB a diameter, and P′ a point in the curve indefinitely near to P; then P′ will ultimately be on the line PT, and the parallelograms P′C, P′B will be equal. But because AB = AT (CONIC SECTIONS, vol. vii., p. 255, prop. ix.), PD = ½PC, therefore the parallelogram P′B is double the parallelogram P′D; and, if we take a succession of points, such as PP′, indefinitely near to each other, the areas APB, APD may be conceived to be made up of parallelograms, every parallelogram in the area APB being double the corresponding parallelogram in APD. Hence the area APB is double APD, or APB is ⅔ the parallelogram ABPD. From this it follows that PAp = ⅔PDdp; *or the area of a parabola is two-thirds of the circumscribed parallelogram.*



Example.—The base of a parabolic segment is 10 and its height 4.

$$\text{The area} = \tfrac{2}{3} \times 10 \times 4 = 26\tfrac{2}{3}.$$

109. *To find the Volume of a Paraboloid.*—The parabola ABD (fig. art. 106) revolving about AD $= h$, generates the paraboloid whose volume

$$= \pi\int_0^h y^2dx = 4\pi m\int_0^h x\,dx = 2\pi mh^2.$$

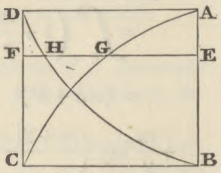
Or if BD $= b$, since $4mh = b^2$,

$$\text{the volume} = \tfrac{1}{2}\pi b^2h.$$

The cylinder whose base is the circle described by the revolution of BD, and whose altitude is AD, $= \pi b^2h$.

Whence a paraboloid is equal to one-half its circumscribing cylinder.

110. The same result may also be obtained thus:—If AGC and BHD be two equal parabolas, whose vertices are A, B, and if the figure revolve round AB, ABCD will describe a cylinder, and the parabolas will describe paraboloids. If we also suppose that the solids are cut by a number of planes indefinitely near to each other and parallel to the base of the cylinder, we may conceive the solids to be made up of elementary cylinders constituted between the contiguous planes.



Now, if $y^2 = px$ be the equation to the parabolas,

$$\text{EG}^2 = p\cdot\text{AE, and EH}^2 = p\cdot\text{EB};$$

$$\therefore \text{EG}^2 + \text{EH}^2 = p\cdot(\text{AE} + \text{BE}) = p\cdot\text{AB} = \text{BC}^2 = \text{EF}^2.$$

Also if we put h for the height of the cylinders whose bases are in the plane described by EF, their volumes will be $\pi h\cdot\text{EG}^2$, $\pi h\cdot\text{EH}^2$, $\pi h\cdot\text{EF}^2$; and since $\pi h\cdot\text{EG}^2 + \pi h\cdot\text{EH}^2 = \pi h\cdot\text{EF}^2$, and a similar relation exists for every corresponding set of cylinders, it follows that the elementary cylinders which constitute the paraboloids are ultimately equal to those which constitute the whole cylinder.

Hence the two paraboloids are together equal to the whole cylinder; and since the paraboloids are equal to each other, each is equal to half the cylinder.

Example.—The diameter of the base of a paraboloid is 10, and its height 4.

$$\text{Here } h = 4, \text{ and } b = 5.$$

$$\text{The volume} = \tfrac{1}{2}\pi \times 25 \times 4 = 157{\cdot}0795.$$

111. *To find the Volume of the Frustum of a Paraboloid.*—The frustum is generated by the revolution of BDMP (fig. art. 106) about DM, where if AD $= h_1$, AM $= h_2$, DM $= h$, BD $= b_1$, MP $= b_2$,

$$\text{the volume} = \pi\int_{h_2}^{h_1} y^2dx = 4\pi m\int_{h_2}^{h_1} x\,dx$$

$$= 2\pi m(h_1^2 - h_2^2) = 2\pi m(h_1 + h_2)\,h$$

$$= \tfrac{1}{2}\pi(4mh_1 + 4mh_2)h = \tfrac{1}{2}\pi(b_1^2 + b_2^2)h.$$

Or otherwise, the volume of the frustum is equal to the difference of the paraboloids generated by ABD, AMP

$$= \tfrac{1}{2}\pi(b_1^2h_1 - b_2^2h_2) = 2m\pi(h_1^2 - h_2^2)$$

$$= \tfrac{1}{2}\pi(b^{\,2} + b_2^2)h.$$

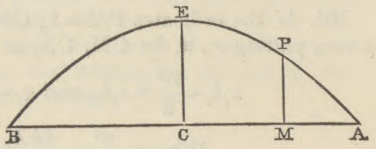
Now since πb_1^2, πb_2^2 are the areas of the circles generated by the revolution of BD and MP, it follows that *the volume of the frustum of a paraboloid is equal to half the sum of the areas of its ends multiplied by its height.*

Example.—The radii of the ends of the frustum of a paraboloid are 3 and 6, and its height is 3.

$$\text{The volume} = \frac{\pi}{2} \times (36 + 9) \times 3$$

$$= 212{\cdot}058.$$

112. *To find the Volume of a Parabolic Spindle.*—The parabolic spindle is generated by the revolution of the parabola AEB about AB, a line at right angles to CE, the axis of the curve.



If CM $= x$, and MP $= y$, the equation to the curve is

$$y = a - \frac{x^2}{p}, \text{ where EC} = a.$$

Wherefore, if AC $= b$, we have $b^2 = ap$, and the volume generated by the revolution of ACE

$$= \pi\int_0^b y^2dx = \pi\int_0^b \left(a^2 - \frac{2ax^2}{p} + \frac{x^4}{p^2}\right)dx$$

$$= \frac{8}{15}\pi a^2b.$$

Hence the volume generated by the revolution of AEB *is equal to* $\tfrac{8}{15}$ *of a circumscribed cylinder.*

Example.—The length of a parabolic spindle is 12, and its middle diameter is 8.

$$\text{Here } a = 4,\ 2b = 12.$$

$$\text{The volume} = \frac{8}{15}\pi \times 16 \times 12 = 321{\cdot}699.$$

113. *To find the Volume of the Frustum of a Parabolic Spindle.*—The frustum is generated by the revolution of CEPM about CM.

If PM $=a'$, and CM $=h$, from the equation to the parabola

$$a'=a-\frac{h^2}{p},$$

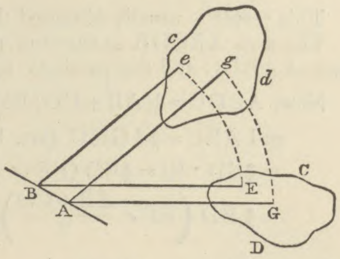
$$\text{and the volume }=\int_0^h\left(a^2-\frac{2ax^2}{p}+\frac{x^4}{p^2}\right)dx$$
$$=\frac{\pi h}{15}(8a^2+4aa'+3a'^2).$$

Example.—Find the volume of the frustum of a parabolic spindle, the radius of the end passing through the centre of the entire spindle being 16, the radius of the other end 12, and the length 20.

$$\text{The volume}=\frac{20\pi}{15}(8\times 256+4\times 16\times 12+3\times 144)$$
$$=13605\cdot 19.$$

SECTION VII.—ON THE DETERMINATION OF THE VOLUMES AND SURFACES OF SOLIDS OF REVOLUTION, GENERATED BY PLANE FIGURES WHOSE AREAS AND CENTRES OF GRAVITY ARE KNOWN.

114. Let a solid be generated by any plane figure CD, revolving round an axis AB, in the same plane, but which is supposed not to cut CD. The area CD, and the distance AG of the centre of gravity of CD from the axis AB, being known, it is required to find the volume and surface of the solid.



(i.) *To find the volume of the solid.* — Let the plane of the figure CD, in its initial position, be the plane of (x, y); let AB be the axis of x, and let θ be the angle GAg through which CD revolves. Then an elementary area $\delta x\delta y$ of the figure CD, in revolving through an angle $\delta\theta$, will generate an elementary solid whose volume is $y\delta\theta\delta x\delta y$. Therefore the whole solid

$$=\int_0^\theta\iint y\,d\theta\,dx\,dy=\theta\iint dx\,dy.$$

The limits of x and y will depend upon the nature of the revolving curve. But if $\bar{y}$ be the distance AG of the centre of gravity from AB, we shall have, from the nature of the centre of gravity,

$$\bar{y}=\frac{\iint y\,dx\,dy}{\iint y\,dx\,dy};$$

the limits of x and y being the same as before. Therefore the whole solid

$$=\theta\bar{y}\iint dx\,dy=\text{arc G}g\times\text{area CD}.$$

A more elementary proof may be obtained as follows:—If A, the area CD, be made up of the elements a_1, a_2, ... a_n, whose respective distances from AB are y_1, y_2 . . . . . y_n: then the solid generated by the element a_1 at E

$$=a_1\times\text{arc E}e=a_1\times\text{BE}\times\text{angle EB}e=a_1y_1\theta;$$

and the whole solid

$$=\theta(a_1y_1+a_2y_2+\;.\;.\;.\;.\;.\;+a_ny_n)=\theta\bar{y}\text{A},$$
$$=\text{arc G}g\times\text{area CD}.$$

Hence if any plane figure revolve about an axis which lies in the same plane with it, but does not cut it, the volume of the solid which is generated is equal to a prism whose base is the revolving figure, and whose height is the length of the path described by the centre of gravity of the area of the plane figure.

If the figure CD make a complete revolution round AB, $\theta=2\pi$;

$\therefore$ the solid = area CD × circle whose radius is AG.

115. (ii.) *To find the surface of the solid.*—The surface generated by an element δs of the perimeter of the figure CD, revolving through an angle $\delta\theta$, is $y\delta\theta\delta s$; therefore the whole surface

$$=\int_0^\theta\int y\,d\theta\,ds=\theta\int y\,ds.$$

The limits depend upon the nature of the figure CD; but if $\bar{y}=$ AG, the distance of the centre of gravity of the perimeter of CD, from AB,

$$\bar{y}=\frac{\int y\,ds}{\int ds}.$$

Therefore the surface of the solid generated by CD

$$=\theta\bar{y}\int ds=\text{arc G}g\times\text{perimeter of CD}.$$

The same result may be obtained, if in the second demonstration of the last proposition we substitute the elements of the perimeter of CD for those of the surface CD.

Hence if any plane figure revolve about an axis in the same plane with it, but which does not cut it, the surface of the solid which is generated is equal to a rectangle whose base is the perimeter of the revolving figure, and whose altitude is the length of the path described by the centre of gravity of the perimeter.

If the figure CD make a complete revolution, the surface of the solid

= perimeter of CD × circle whose radius is Ag.

116. *To find the Volume and Surface of a Circular Ring.*—Let a be the distance of the centre of the generating circle from the axis round which it revolves to generate the ring, and r the radius of the generating circle.

Then the path described by the centre of gravity, either of the area or perimeter of the generating circle $=2\pi a$.

Also area of circle $=\pi r^2$.
Perimeter of circle $=2\pi r$.
Hence volume of ring $=2\pi^2ar^2$.
Surface of ring $=4\pi^2ar$.

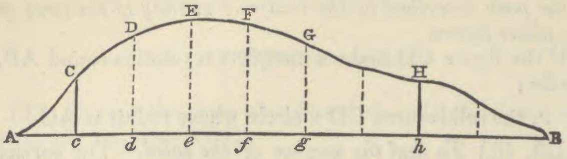
Example.—Find the volume and surface of a ring 4 inches thick, and whose internal diameter is 6 inches.

Here the radius of the generating circle is 2 inches, and the radius of the circle described by the centre of gravity is 5 inches.

Volume of ring $=2\pi^2\times 5\times 2^2$
$=40\times 9\cdot 8696044=394\cdot 784$ cubic inches.
Surface of ring $=4\pi^2\times 2\times 5$
$=40\pi^2=394\cdot 784$ square inches.

SECTION VIII.—ON THE APPROXIMATE DETERMINATION OF THE AREAS OF CURVES, AND THE VOLUMES OF SOLIDS, BY MEANS OF EQUIDISTANT ORDINATES, OR EQUIDISTANT SECTIONS.

117. Let AEB be any curve, and let the ordinates Cc, Dd, &c., be drawn perpendicular to AB, dividing it into equal parts. Having given the lengths of the ordinates and their common distance, it is required to determine, either accurately or approximately, the areas of the whole curve AEB, or of the portion CEH*hc*; and also the volumes of the solids generated by the revolution of these figures about the line AB.



118. *To find the Area of the Curve.*—(i.) As the ordinates C*c*, D*d*, &c., are supposed to be near to each other, if straight lines be drawn between AC, CD, &c., these lines will nearly coincide with the curve, and its area will be nearly equal to the sum of the two triangles AC*c*, BH*h*, and the trapezoids CD*dc*, DE*dc*, &c.

Hence, putting

$$\mathrm{C}c=a_1,\ \mathrm{D}d=a_2,\ \ldots\ \mathrm{H}h=a_n, \text{ and } \mathrm{A}c=cd=\&\text{c.}=h,$$

we may assume (arts. 10, 14) that the surface AEB is nearly equal to

$$\tfrac{1}{2}a_1h+\tfrac{1}{2}(a_1+a_2)h+\tfrac{1}{2}(a_2+a_3)h+\ \ldots\ +\tfrac{1}{2}a_nh;$$

$$\text{or area}=h(a_1+a_2+a_3+\ \ldots\ +a_n) \text{ nearly.}$$

Similarly it may be shown that the area of the figure CEH*hc*

$$=\tfrac{1}{2}h\{a_1+a_n+2(a_2+a_3+\ \ldots\ +a_{n-1})\} \text{ nearly.}$$

Therefore *the area of any figure contained by a straight line and a curve is equal to the sum of the equidistant ordinates multiplied by their common distance; or if the figure be contained by a straight line, two perpendiculars at its ends, and a curve, its area is equal to the two perpendiculars added to twice the sum of the intermediate ordinates, and multiplied by half their common distance.*

Example 1.—In a figure AEB, the ordinates are 5, 7, 9, 13, 8, 6, and 4, and their common distance 3.

$$\text{The area}=3\,(5+7+9+13+8+6+4)=156 \text{ nearly.}$$

Example 2.—In a figure such as CEH*hc*, where the ordinates taken in order are a_1, a_2, ... a_7; the common distance of the ordinates = 1, and their values are as follows:—

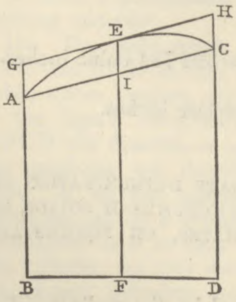
$$\begin{array}{r}
a_2=10\cdot9087121\\
a_3=11\cdot3137085\\
a_4=11\cdot6189500\\
a_5=11\cdot8321596\\
a_6=11\cdot9582607\\
\hline
\text{Sum}=57\cdot6317909\\
2\\
\hline
115\cdot2635818
\end{array}
\qquad
\begin{array}{r}
a_1=10\cdot3923048\\
a_7=12\\
\hline
22\cdot3923048\\
115\cdot2635818\\
\hline
2)\overline{137\cdot6558866}\\
\hline
\text{area}=68\cdot8279433
\end{array}$$

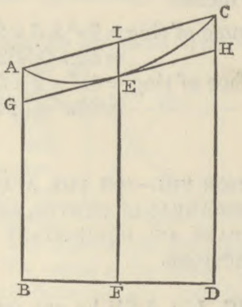
119. (ii.) A very close approximation to the areas of any curvilineal figures, such as AEB or C*ch*H (fig. art. 117), may generally be obtained by the following method:—

Let *ch* (art. 117) be divided into any *even* number of equal parts; and let ABDC (art. 119) represent a portion of the figure C*ch*H (art. 117), such as C*ce*E terminated by two *odd* ordinates C*c*, E*e*; then a curve, whose equation is

$$y=m+nx+px^2,$$

may be supposed to pass through the points A, E, C (art. 119): and since these points are near each other, the curve will coincide either accurately or very nearly with the curve AEC.





Let F be the origin, and put AB = a_1, EF = a_2, CD = a_3, and BF = FD = h.

$$\begin{array}{rl}
\text{Then when } x= & 0,\ y=a_2\\
x= & h,\ y=a_3\\
x= & -h,\ y=a_1:
\end{array}$$

and substituting in the equation, we obtain

$$\begin{array}{l}
a_2=m\\
a_1=a_2-nh+ph^2\\
a_3=a_2+nh+ph^2.
\end{array}$$

$$\text{Whence } n=\frac{a_3-a_1}{2h};\ p=\frac{a_3-2a_2+a_1}{2h^2}.$$

We have then the area AECDB

$$=\int_{-h}^{h}ydx=\int_{-h}^{h}(m+nx+px^2)\,dx$$

$$=2\left(mh+\frac{ph^3}{3}\right)=\tfrac{1}{3}h(a_1+4a_2+a_3).$$

This result is usually obtained thus:—

The area AECDB is the sum or difference of the trapezoid ABDC and the parabolic segment AEC.

Now, $\mathrm{ABDC}=\tfrac{1}{2}(\mathrm{AB}+\mathrm{CD})\,\mathrm{BD}=(a_1+a_3)\,h$ (art. 14);

and $\mathrm{AEC}=\tfrac{2}{3}\mathrm{AGHC}$ (art. 108).

$$=\tfrac{2}{3}\mathrm{BD}\cdot\mathrm{EI}=\tfrac{2}{3}\mathrm{BD}\,(\mathrm{EF}\backsim\mathrm{IF})$$

$$=\tfrac{2}{3}\,\mathrm{BD}\left(\mathrm{EF}\backsim\frac{\mathrm{AB}+\mathrm{CD}}{2}\right)=\tfrac{4}{3}h\left(a_2\backsim\frac{a_1+a_3}{2}\right)$$

Therefore the area AECDB

$$=h(a_1+a_3)\pm\tfrac{4}{3}h\left(a_2\backsim\frac{a_1+a_3}{2}\right)$$

$$=\tfrac{1}{3}h(a_1+4a_2+a_3).$$

120. If now we put (fig. art. 117) the ordinates C*c* = a_1, D*d* = a_2, E*e* = a_3, ... H*h* = a_n,

$$\text{we have } \mathrm{C}ce\mathrm{E}=\tfrac{1}{3}h(a_1+4a_2+a_3);$$

$$\mathrm{E}eg\mathrm{G}=\tfrac{1}{3}h(a_3+4a_4+a_5),\ \&\text{c.}$$

Therefore the figure C*ch*H

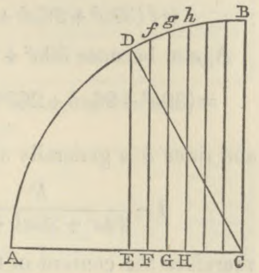
$$=\tfrac{1}{3}h\{a_1+a^n+2(a_3+a_5+\ldots+a_{n-2})+4(a_2+a_4+\ldots+a_{n-1})\}.$$

121. The area ABGD may be derived from C*ch*H by putting $a_1=a_n=0$. Substituting $a_1 \ldots a_r$ for the remaining ordinates $a_2 \ldots a_{n-1}$, we then obtain the figure ABGD

$$=\tfrac{2}{3}h\{a_2+a_4+\ldots+a_{r-1}+2(a_1+a_3+\ldots a_r)\}.$$

122. From the preceding demonstrations it follows, that the area of any curvilineal figure, such as C*ch*H (art. 117) whose base is divided into an *even number* of equal parts by equidistant ordinates, is obtained by the following rule:—*Add together the two extreme ordinates, twice the sum of the intermediate odd ordinates, and four times the sum of the even ones. Multiply the result by the common distance of the ordinates, and one-third of the sum is the area, either accurately or approximately.* A similar rule may be derived from the formula of article 121 for areas such as ABGD.

According to the relation subsisting between the ordinates a_1, a_2, a_3, the equation of art. 119 will be that of a straight line or a parabola; hence the result obtained by the above rule will be strictly accurate in the case of all figures, such as C*ch*H (fig. art. 117), having those portions of their boundaries CDE, EFG, which are terminated by the odd ordinates, either straight lines or parabolic arcs. The curve CEH may therefore be either wholly convex or wholly concave, towards AB, or partly convex and partly concave, provided in the latter case the points of contrary flexure occur only at the odd ordinates; for otherwise the intermediate arcs could not be, even approximately, parabolic. When points of contrary flexure occur, ordinates may be drawn at those points, and the intermediate areas, being found separately, may be added to obtain the whole surface. In other cases where there are numerous points of contrary flexure, the formula of art. 118 will probably give as good an approximation to the area of the curve as that obtained by the more complex formula of art. 121.



Example.—To find the area of a quadrant of a circle. Draw DE bisecting AC at right angles, then BD is an arc of 30°, and the quadrant ABC $=3$ sector DBC $=3\{\mathrm{BCED}-\mathrm{CED}\}$; $\mathrm{DE}^2=\mathrm{DC}^2-\mathrm{EC}^2$, if we put $\mathrm{DE}=a_1$, $\mathrm{F}f=a_2$, &c., we have

$$a_1^2=144-36=108$$
$$a_2^2=144-25=119, \&c;$$

$$\begin{aligned}\therefore\ a_1&=10{\cdot}3923048\\ a_2&=10{\cdot}9087121\\ a_3&=11{\cdot}3137085\\ a&=11{\cdot}6189500\\ a_5&=11{\cdot}8321596\\ a_6&=11{\cdot}9582607\\ a_7&=12{\cdot}0000000\end{aligned}$$

also $h=\frac{1}{6}\mathrm{EC}=1$

The area is then calculated as follows :—

$$\begin{array}{rr} a_2= & 10{\cdot}9087121\\ a_4= & 11{\cdot}6189500\\ a_6= & \underline{11{\cdot}9582607}\\ & 34{\cdot}4859228\\ & \underline{4}\\ & 137{\cdot}9436912\\ a_3= & 11{\cdot}3137085\\ a_5= & \underline{11{\cdot}8321596}\\ & 23{\cdot}1458681\\ & \underline{2}\\ & 46{\cdot}2917362 \end{array} \qquad \begin{array}{rr} a_1= & 10{\cdot}3923048\\ a_7= & 12{\cdot}0000000\\ & 137{\cdot}9436912\\ & \underline{46{\cdot}2917362}\\ & 3)206{\cdot}6277322\\ \mathrm{BCDE}= & 68{\cdot}8759107\\ \mathrm{DEC}=\frac{1}{2}\mathrm{CE}\cdot\mathrm{DE}= & \underline{31{\cdot}1769144}\\ & 37{\cdot}6989963\\ & \underline{3}\\ \text{quadrant}= & 113{\cdot}0969889 \end{array}$$

The quadrant whose radius is unity, obtained by dividing by 144, is ·785396, which is correct to five places of decimals. The area of BCDE, calculated by the rule of art. 118, is 68·8279433 from which the quadrant whose radius is unity, is found to be ·789396, a result correct only to two places.

123. *To find the Volume of a Solid of Revolution.*—The solid is supposed to be generated by the revolution of the figure CEH*hc* (art. 117) about the line AB.

Let ABCD (fig. art. 119) be a portion of the figure (art. 117) such as CE*ec*, terminated by two *odd* ordinates; and assuming EF, FD as axes, let

$$y^2=m+nx+px^2$$

be the equation of a curve of the second degree passing through the points A, E, C. Then if we put

$$\mathrm{AB}=a_1,\ \mathrm{EF}=a_2,\ \mathrm{CD}=a_3, \text{ and } \mathrm{BF}=\mathrm{FD}=h,$$

it will be found, as in art. 119, that

$$m=a_2^2,\ n=\frac{a_3^2-a_1^2}{2h},\ p=\frac{a_3^2-2a_2^2+a_1^2}{2h^2}$$

Hence the volume generated by ABDCE

$$=\pi\int_{-h}^{h}y^2dx=\pi\int_{-h}^{h}(m+nx+px^2)=\frac{\pi h}{3}(a_1^2+4a_2^2+a_3^2).$$

124. A less rigorous demonstration of the same result may also be obtained by assuming that the points A, E, and C, are taken so near each other, that the solid generated by ABDCE differs little from the frustum of a cone; for, by art. 66, its volume will evidently be

$$\tfrac{1}{6}\mathrm{BD}(\pi a_1^2+4\pi a_2^2+\pi a_3^2)=\tfrac{1}{3}\pi h(a_1^2+4a_2^2+a_3^2).$$

125. If now we put in the figure of art. 117 as formerly,

$$\mathrm{C}c=a_1,\ \mathrm{D}d=a_2,\ \mathrm{H}h=a_n, \&c., \text{ and } cd=de=\&c.=h,$$

the volumes generated by CE*ec*, EG*ge*, &c., will be respectively

$$\tfrac{1}{3}\pi h(a_1^2+4a_2^2+a_3^2),\ \tfrac{1}{3}\pi h(a_3^2+4a_4^2+a_5^2)\ \ldots\ldots$$
$$\tfrac{1}{3}\pi h\,(a_{n-2}^2+4a_{n-1}^2+a_n^2).$$

Whence the whole solid of revolution generated by C*ch*H will be

$$\tfrac{1}{3}\pi h\{a_1^2+a_n^2+2(a_3^2+a_5^2+..a_{n-2}^2)+4(a_2^2+a_4^2+..+a_{n-1}^2)\}.$$

Example.—To find the volume of the frustum of a sphere generated by the revolution of BDEC, in the figure to art. 122, we have the values of a_1^2 a_2^2 as follows :—

$$\begin{array}{r} a_2^2=119\\ a_4^2=135\\ a_6^2=\underline{143}\\ 397\\ \underline{4}\\ 1588\\ a_3^2=128\\ a_5^2=\underline{140}\\ 268\\ \underline{2}\\ 536 \end{array} \qquad \begin{array}{r} a_1^2=108\\ a_7^2=144\\ 1588\\ \underline{536}\\ 2376 \end{array}$$

$\therefore$ the volume of the frustum

$$=\frac{\pi}{3}\times 2376$$
$$=2488{\cdot}1413816;$$

which agrees accurately with the value found by the formula of article 81.

126. As it may sometimes be more convenient to measure equidistant circumferences of the solid of revolution than equidistant radii; let $c_1, c_2, \ldots. c_n$, be the circumferences of the circles described by the revolving points C, D, &c. (art. 117).

Then, since $\pi a_1^2=\frac{c_1^2}{4\pi}$, $\pi a_2^2=\frac{c_2^2}{4\pi}$, &c. (art. 56),

the volume of the solid of revolution will be

$$\frac{h}{12\pi}\{c_1^2+c_n^2+2(c_3^2+c_5^2+..+c_{n-2}^2)+4(c_2^2+c_4^2+..+c_{n-1}^2)\}.$$

127. Also, since $\pi a_1^2, \pi a_2^2 \ldots. \pi a_n^2$, are the areas of the circles described by the revolving ordinates $a_1, a_2, \ldots. a_n$, if $s_1, s_2, \ldots. s_n$, be put for these areas, the volume of the solid of revolution will be

$$\tfrac{1}{3}h\{s_1^2+s_n^2+2(s_3^2+s_5^2+\ldots+s_{n-2}^2)+4\,(s_2^2+s_4^2+\ldots+s_{n-1}^2)\}.$$

128. In the figure AEB (art. 117) $a_1=o$, and $a_n=o$; therefore the volume of the solid generated by its revolution

$$=\tfrac{2}{3}\pi h\{a_2^2+a_4^2+\ldots.\ a_{n-1}^2+2(a_1^2+a_3^2+\ \ldots.\ a_n^2)\};$$

and the formulæ of articles 125, 126 may be similarly modified.

The equation of art. 123 may either be that of a straight line, a circle, an ellipse, or a hyperbola, according to the relations which may subsist between the ordinates a_1, a_2, a_3. Hence the formulæ of arts. 124–128 will be strictly accurate for solids generated by the revolution of areas bounded by any of these lines, subject to the limitation stated in art. 122.

129. If the curve which generates the solid of revolution be everywhere convex to the axis of the solid, the volume may be obtained by a somewhat simpler formula than that of art. 124.

Let the base of the figure be divided into *any* number of equal parts by the ordinates $a_1, a_2, \ldots a_n$, whose common distance is h.

Then if a parabola be described passing through the points AE (fig. art. 119), and whose axis is the line BF, it will coincide either nearly or exactly with the curve AE; and by art. 111 the paraboloid generated by AEBF,

$$=\tfrac{1}{2}\pi(a_1{}^2+a_2{}^2)h.$$

Similarly if another parabola be described passing through the points E and C, the volume generated by ECDF

$$=\tfrac{1}{2}\pi(a_2{}^2+a_3{}^2)h.$$

Therefore proceeding as in art. 125, the volume of the whole solid of revolution

$$=\tfrac{1}{2}\pi h\{a_1{}^2+a_n{}^2+2(a_2{}^2+a_3{}^2+\ldots\ldots+a_{n-1}^2)\}.$$

Example.—The volume of the segment of a sphere which is calculated in the example to art. 124, may be found as follows:—

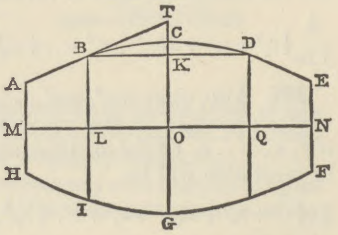
$$\begin{array}{rl}
a_2{}^2=119 & \quad a_1{}^2=108 \\
a_3{}^2=128 & \quad a_7{}^2=144 \\
a_4{}^2=135 & \quad \phantom{a_7{}^2=}1330 \\
a_5{}^2=140 & \quad \phantom{a_7{}^2=}\overline{1582} \\
a_6{}^2=143 & \\
\overline{665} & \quad \therefore \text{volume}=\frac{\pi}{2}\times 1582 \\
2 & \quad \phantom{\therefore \text{volume}}=2485 \text{ nearly.} \\
\overline{1330} &
\end{array}$$

130. *To find the Volume of any Solid.*—Let $s_1, s_2, \ldots s_n$, be the areas of equidistant sections, taken so near each other that every two consecutive sections may be regarded as sensibly similar. Then, since it has been proved in art. 39 that the volume of any prismoidal solid, of which $s_1{}^2, s_2{}^2, s_3{}^2$ are the areas of the ends and middle section, and h half the height, is $\frac{1}{3}h(s_1{}^2+4s_2{}^2+s_3{}^2)$; if we proceed as in art. 125, we shall find that the volume of the solid is expressed by the formula of art. 127, which therefore applies not only to solids of revolution, but approximately to all solids whatever.

ON GAUGING.

Gauging denotes the measurement of casks or of substances liable to excise duties.

To Compute the Contents of a Cask from its Length and Diameters at the Middle and End.—Let the axis of the cask MN be trisected in L and Q; then the usual form of a cask is such that we may assume AB, DE to be straight lines, and BCD the arc of a parabola whose axis is CO. The portions of the cask AI, DF will then be frusta of cones, and DI will be the frustum of a parabolic spindle.



Put $CG=a$, $AH=b$, $BI=c$, and $ML=LQ=QN=\frac{1}{3}l$. Then the volume generated by AL or DN

$$=\frac{\pi l}{180}(5b^2+5bc+5c^2)\ (\text{art. } 65);$$

and the volume generated by BQ

$$=\frac{\pi l}{180}(8a^2+4ac+3c^2)\ (\text{art. } 113).$$

Now if AB be produced to T, because TB is a tangent to the parabola BC, TK = 2CK, and by similar triangles

$$\text{TK} : \text{BL}-\text{AM} :: \text{BK} : \text{ML}, \text{ or } 2(a-c) : c-b :: 1 : 2;$$

from which $c=\frac{1}{5}(4a+b)$. Therefore substituting for c, and adding, we obtain the whole content of the cask

$$=\frac{l}{360}(39{\cdot}04a^2+25{\cdot}92ab+25{\cdot}04b^2)$$

$$=\frac{\pi l}{360}(39a^2+26ab+25b^2) \text{ nearly.}$$

If a, b, and l are expressed in inches, since there are 277·3 cubic inches in a gallon, and

$$\frac{\pi}{360\times 277{\cdot}3}={\cdot}000031470,$$

the contents of the cask in imperial gallons

$$=l(39a^2+26ab+25b^2)\times{\cdot}00003147 \quad . \quad . \quad (1.)$$

Again, because $39a^2+26ab+25b^2$

$$=(39a^2+26ab+26b^2)\left(1-\frac{b^2}{39a^2+26ab+26b^2}\right);$$

and since b is generally about $\frac{3}{4}a$,

$$1-\frac{b^2}{39a^2+26ab+26b^2}=1-\frac{1}{129}=\frac{128}{129};$$

therefore the content of the cask in gallons

$$=l(39a^2+26ab+26b^2)\times\frac{128}{129}\times{\cdot}0003147$$

$$=l(\tfrac{2}{3}a^2+ab+b^2)\times{\cdot}000812 \text{ nearly} \quad . \quad . \quad . \quad (2.)$$

Example.—Let the bung and head diameters of a cask be 32 and 24 inches respectively, and its length 40 inches; required its content in gallons.

By formula (1) the content

$$=(39\times 32^2+25\times 24^2+32\times 24\times 26)\times 40\times{\cdot}00003147$$

$$=93{\cdot}29 \text{ gallons.}$$

By formula (2) the content

$$=(\tfrac{2}{3}\times 32^2+24^2+32\times 24)\times 40\times{\cdot}000812=93{\cdot}54 \text{ gallons.}$$

The contents of casks of any forms to which the preceding formulæ may not apply, may be determined with great accuracy by the following method.

If a and b be the bung and head diameters, c the diameter equidistant from the bung and head, and l the length of the cask, all in inches, it is obvious, by article 124, that the capacity of the cask in gallons

$$=\frac{\frac{1}{4}\pi l}{3\times 4\times 277{\cdot}3}(2a^2+2b^2+8c^2)$$

$$=l\{a^2+b^2+(2c)^2\}\times{\cdot}00047205.$$

Example.—Let the bung and head diameters be 32 and 24, the middle diameter 30·2, and the length of the cask 40. The capacity

$$=40\times\{(32)^2+(24)^2+(60{\cdot}4)^2\}\times{\cdot}000472=99{\cdot}1 \text{ gallons.}$$

To find the Ullage of a Cask.—The quantity of liquor contained in a cask partially filled, and the capacity of the portion which is empty, are termed respectively the wet and dry ullage.

(i.) The ullage of a standing cask is found by the method of article 124 as follows:—

Add the square of the diameter at the surface, the square of the diameter at the nearest end, and the square of double the diameter half way between; multiply the sum by the length between the surface and the nearest end, and by ·000472. The product will be the wet or dry ullage, according as the lesser portion of the cask is filled or empty.

(ii.) The ullage of a lying cask is found approximately on the assumption that it is proportional to the segment of the bung circle cut off by the surface of the liquor. The rule adopted in practice is,

$$\text{ullage}=\tfrac{5}{4}\text{ content of cask}\times\text{segmental area.}$$

TABLE I.—*Areas of Polygons.*

Number of Sides.	Polygon Side = 1.	Area.	Log Area.
3	Equilateral Triangle.........	0·4330127	9·6365006
4	Square.............................	1·0000000	0·0000000
5	Pentagon..........................	1·7204774	0·2356490
6	Hexagon	2·5980762	0·4146519
7	Heptagon..........................	3·6339125	0·5603745
8	Octagon	4·8284271	0·6380568
9	Nonagon...........................	6·1818242	0·7911166
10	Decagon...........................	7·6942088	0·8861640
11	Undecagon........................	9·3656407	0·9715375
12	Dodecagon........................	11·1961524	1·0490688

TABLE II.—*Surfaces and Volumes of Regular Polyhedrons*

Polyhedron.	Number and Nature of Faces.	Surface.	Log Surface.	Volume.	Log Volume.
Tetrahedron...	4 equilat. triangles	1·7320508	0·2385606	0·1178511	0·0713338
Hexahedron...	6 squares	6·0000000	0·7781513	1·0000000	0·0000000
Octohedron....	8 equilat. triangles	3·4641016	0·5395906	0·4714043	9·6733937
Dodecahedron	12 pentagons	20·6457788	1·3148302	7·6631189	0·8844056
Icosahedron...	20 equilat. triangles	8·6602540	0·9375306	2·1816950	0·3387940

TABLE III.—*Functions of* π.

	Number.	Logarithm.		Number.	Logarithm.
π	3·1415927	0·4971499	π^2...	9·8696044	0·9942997
2π ...	6·2831853	0·7981799			
4π ...	12·5663706	1·0992099	$\frac{1}{6\pi^2}$...	0·0168869	8·2275490
$\frac{1}{2}\pi$ ...	1·5707963	0·1961199			
$\frac{1}{3}\pi$ ...	1·0471976	0·0200286	$\sqrt{\pi}$...	1·7724539	0·2485750
$\frac{1}{4}\pi$ ...	0·7853982	9·8950899			
$\frac{1}{6}\pi$ ...	0·5235988	9·7189986	$\sqrt[3]{\pi}$..	1·4645919	0·1657166
$\frac{1}{8}\pi$ ...	0·3926991	9·5940599			
$\frac{1}{12}\pi$ ..	0·2617994	9·4179686	$\frac{1}{\sqrt{\pi}}$...	0·5641896	9·7514251
$\frac{4}{3}\pi$ ...	4·1887902	0·6220886			
$\frac{\pi}{180}$...	0·0174533	8·2418774	$\frac{2}{\sqrt{\pi}}$...	1·1283792	0·0524551
$\frac{1}{\pi}$ ...	0·3183099	9·5028501	$\frac{1}{2\sqrt{\pi}}$	0·2820948	9·4503951
$\frac{4}{\pi}$ ...	1·2732395	0·1049101	$\sqrt[3]{\frac{6}{\pi}}$..	1·2407010	0·0936671
$\frac{1}{4\pi}$...	0·0795775	8·9007901	$\sqrt[3]{\frac{3}{4\pi}}$	0·6203505	9·7926371
$\frac{180}{\pi}$...	57·2957795	1·7581226	$\log_e \pi$	1.1447299	0·0587030

TABLE IV.—*Lengths of Circular Arcs* (*Radius* = 1.)

Degrees.	Arc.	Degrees.	Arc.	Degrees.	Arc.	Minutes.	Arc ·0	Seconds.	Arc ·00
1	·0174533	61	1·0646508	121	2·1118484	1	002909	1	0048
2	·0349066	62	1·0821041	122	2·1293017	2	005818	2	0097
3	·0523599	63	1·0995574	123	2·1467550	3	008727	3	0145
4	·0698132	64	1·1170107	124	2·1642083	4	011636	4	0194
5	·0872665	65	1·1344640	125	2·1816616	5	014544	5	0242
6	·1047198	66	1·1519173	126	2·1991149	6	017453	6	0291
7	·1221730	67	1·1693706	127	2.2165682	7	020362	7	0339
8	·1396263	68	1·1868239	128	2·2340214	8	023271	8	0388
9	·1570796	69	1·2042772	129	2·2514747	9	026180	9	0436
10	·1745329	70	1·2217305	130	2·2689280	10	029089	10	0485
20	·3490659	80	1·3962634	140	2·4434610	20	058178	20	0970
30	·5235988	90	1·5707963	150	2·6179939	30	087266	30	1454
40	·6981317	100	1·7453293	160	2·7925268	40	116355	40	1939
50	·8726646	110	1·9198622	170	2·9670597	50	145444	50	2424
60	1·0471976	120	2·0943951	180	3·1415927	60	174533	60	2909

TABLE V.—*Areas of Segments of a Circle* (*Radius* = 1.)

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
·01	·001883	·26	·239997	·51	·631563	·76	1·095445
·02	·005317	·27	·253558	·52	·649053	·77	1·114885
·03	·009754	·28	·267333	·53	·666652	·78	1·134372
·04	·014994	·29	·281315	·54	·684358	·79	1·153904
·05	·020923	·30	·295499	·55	·702168	·80	1·173479
·06	·027462	·31	·309879	·56	·720079	·81	1·193095
·07	·034553	·32	·324449	·57	·738087	·82	1·212750
·08	·042151	·33	·339206	·58	·756191	·83	1·232441
·09	·050219	·34	·354142	·59	·774387	·84	1·252167
·10	·058726	·35	·369255	·60	·792673	·85	1·271925
·11	·067646	·36	·384538	·61	·811047	·86	1·291714
·12	·076957	·37	·399988	·62	·829505	·87	1·311531
·13	·086679	·38	·415601	·63	·848046	·88	1·331374
·14	·096674	·39	·431371	·64	·866666	·89	1·351241
·15	·107046	·40	·447295	·65	·885363	·90	1·371130
·16	·117741	·41	·463370	·66	·904135	·91	1·391040
·17	·128745	·42	·479590	·67	·922979	·92	1·410967
·18	·140047	·43	·495953	·68	·941893	·93	1·430911
·19	·151636	·44	·512455	·69	·960875	·94	1·450868
·20	·163501	·45	·529092	·70	·979922	·95	1·470838
·21	·175633	·46	·545860	·71	·999032	·96	1·490818
·22	·188022	·47	·562757	·72	1·018202	·97	1·510805
·23	·200661	·48	·579779	·73	1·037431	·98	1·530799
·24	·213542	·49	·596923	·74	1·056716	·99	1·550797
·25	·226656	·50	·614185	·75	1·076055	1·00	1·570796

(W. S.)

MENTAL DISEASES.

MENTAL DISEASE, MENTAL DERANGEMENT, or MENTAL ALIENATION, comprises two great and distinct classes of morbid affections of the mind,—the one, the result of disease attacking a person of sound mind, is called *Insanity* or *Lunacy;* the other, the result of original or congenital conditions of the individual, is called *Idiocy*, or, in its lesser degrees, *Imbecility*.

All modern physiologists are agreed in regarding the brain as the organ of the mind; it may therefore be stated that these diseases result from affections of the brain,—the one class (insanity) resulting from diseases of a brain originally healthy; the other (idiocy) arising from original defects in the brain, such as imperfect development, or congenital disease of that organ.

Definitions.

Many attempts have been made to define insanity and idiocy; but as the varieties of the mental diseases classed under those general terms are so numerous, and their distinctions in some instances so great, and in others so minute, it may be questioned whether it is possible to define either so as to make the definition of any practical value. Accordingly, most definitions will be found to be either so general and comprehensive as to include sane persons, or so circumscribed as to exclude many who are of unsound mind. Those definitions which will bear criticism will be found to be too general to be of practical use, and to amount to little more than is conveyed in the terms mental derangement or unsoundness. A brief review of the subject will make this apparent, and serve to show in what manner insanity and idiocy can be best described and defined for all legal and practical purposes.

The celebrated Locke incidentally remarked that "madmen do not appear to have lost the faculty of reasoning; but having joined together some ideas very wrongly, they mistake them for truths, and they err, as men do that argue right from wrong principles." Idiots, on the other hand, do not labour under delusions, or mistake mere ideas for truths, but they reason imperfectly. It has accordingly been said that the insane reason rightly from false premises, and idiots reason falsely from right premises. It was the fashion to consider this a definition of insanity and idiocy. But it is obviously no definition at all, as it would include all careless observers among the insane, and consign all illogical reasoners to the category of idiots. Almost all attempts at a definition of insanity, both by medical writers and legal authorities, have been founded on the same idea which occurred to Locke,—namely, that in every case of insanity there was some delusion, and that delusion was, in fact, an essential feature of insanity. This continues to be generally believed even at the present day, and has been laid down in our courts of law authoritatively from the bench. Proceeding upon this assumption, Dr Cullen defined insanity to consist in erroneous or false judgment; and Dr Haslam, to obviate the objection to this as a definition, that some people also make errors in judgment as to facts, added to the definition the impossibility of convincing the insane that this false judgment, error, or delusion, was a delusion. Dr Prichard rendered the definition more precise in his work on "Nervous Disorders," by defining insanity to consist in the conceptions of the mind being mistaken for realities.

More recent authorities have introduced another element into their definitions of insanity,—namely, the loss of self-control—of moral liberty. Thus, M. Morel, one of the latest French writers on insanity, defines it as "une affection cérébrale idiopathique ou sympathique enlevant à l'individu lésé à la fois dans ses fonctions physiologiques et psychologiques, l'exercice de sa liberté morale, et constituant dès lors chez lui une depravation maladire dans ses actes, ses tendances, et ses sentiments ainsi qu'un trouble général ou partiel dans ses idées" (*Etudes Cliniques*, Morel, p. 214). And Mr Noble, the author of the latest systematic work on insanity published in this country, defines it to consist in "chronic disorder of the brain inducing perversion of ideas prejudicial to, or destructive of, the freedom of the will."

The impairment or loss of the power by which we regulate our actions, or the succession of our thoughts, or our judgment regarding external objects or conceptions of the mind, is certainly the most essential peculiarity of insanity; but this seems to be something different from the loss of moral liberty, or the destruction of the freedom of the will. Further, all these definitions seem to assume that there must be some perversion of the understanding—some *delusion* in insanity. This is by no means the case. Nothing is now more fully demonstrated in relation to the insane than this, that there are many cases in which there are no delusions, erroneous impressions, or false judgments, but in which a morbid and ungovernable passion, emotion, or impulse, constitutes the disease. The late Dr Abercrombie was nearer the truth when he described insanity to consist in the undue (morbid?) exercise of one or more powers or faculties of the mind; and idiocy (including dementia) in the deficient exercise or power of the mental faculties. The one consists in a loss of balance; the other in a loss of power,—terms, however, too general for the purposes of a definition.

Assuming that insanity is a disease of the brain, and making provision for cases in which there are no delusions,—cases of what is called moral insanity,—the following definition appears to be as precise as any that can be arrived at;—namely, that it is a chronic cerebral affection, in which emotions, passions, or desires are excited by disease (not by motives), or in which conceptions are mistaken for acts of perception or memory.

This definition distinguishes two classes or general forms of insanity,—one in which the emotions, passions, or desires alone are affected, constituting cases of moral insanity. There may be a general perversion of the emotions and passions without delusions, or a morbid excitement of one particular emotion or passion. In the one case the disease is called mania, or general madness; in the other, monomania or partial insanity.

In the same way the second part of the definition includes those cases in which there may be a general perturbation of the ideas or understanding, general excitement, and incoherent raving on a variety of subjects, referable, therefore, again to mania or general insanity; and also cases in which there is a perversion only in particular trains of thought, or in reference to one object, and referable therefore to monomania or partial insanity. The various forms of insanity are thus arranged in two great classes,—moral and intelligential, or emotional and notional; and in either of these classes it may be either general (mania) or partial (monomania).

The loss of self-control, and of the power of directing the thoughts or correcting the judgment by an act of volition, is an important feature of insanity, and probably constitutes the proximate psychological cause of the mental condition of the insane. As was remarked by Dugald Stewart, the insane are very much like persons asleep, by whom the objects of reverie, and the conceptions which pass through their minds, are believed at the time to have a real existence, because they cannot correct their judgment regarding them by voluntarily referring to the objects by which they are surrounded, as persons do when awake. Thus, in dreams all the persons we see are really believed to be actually before us; the events which are apparently taking place fill us with pleasure or terror according to their character, because they are believed to be realities. Is it not so with the insane? Is it not the suspension of some power of volition, self-direction, or judgment, which makes the insane the sport of their passions and desires, and gives rise in them to the belief in the extraordinary delusions which fill them with ecstasy, terror, or despair?

Idiocy can only be defined in very general terms as a congenital mental deficiency. The degrees of this deficiency are infinitely varied, from the total absence of anything like human thought or reason up to the smallest amount of imbecility which distinguishes a naturally weak-minded person from one of sound mind.

Historical retrospect.

The history of some sciences and arts may with propriety be consigned to oblivion as the cumbrous record of ignorance and error; but the history of this department of study is that of the development of the human mind,—of man himself,—and is therefore deserving of study. The philosophy of mind, and by consequence that of mental diseases and their treatment, has, moreover, by no means attained even at the present day such precision as to render the opinions of previous authors uninteresting or superfluous. (Feuchtersleben, *Principles of Medical Psychology*, p. 23.) A brief historical sketch of the subject may therefore be both instructive and interesting.

The most ancient historical records prove that insanity was recognised in the earliest times. The Israelites were threatened with "madness, and blindness, and astonishment of heart for their transgressions" (Deut. xxviii. 28). David feigned madness before Achish the King of Gath (1 Sam. xxi. 13); and what is more curious, he alleviated the fits of madness to which Saul was subject by his skilful playing on the harp. The influence of music, and of those distractions so much lauded in the present day for the treatment of the insane, appears to have been also well understood by the priests of ancient Egypt. There the temples of Saturn were resorted to by crowds of melancholics. "Whatever gifts of nature or productions of art were calculated to impress the imagination were there united to the solemnities of a splendid and imposing superstition. Games and recreations were instituted in the temples. The most voluptuous productions of the painter and the statuary were exposed to public view. Groves and gardens surrounded those holy retreats, and invited the distracted devotee to refreshing and salubrious exercise. Gaily-decorated boats sometimes transported him to breathe amidst rural concerts the purer breezes of the Nile. In short, all his time was taken up by some pleasurable occupation, or rather by a system of diversified amusements, enhanced and sanctioned by superstition." (*Nosographie Philosophique*, Pinel, tom. ii. 28; Pinel *On Insanity*, by Dr Davis, Introduction, p. xxii.) From the hands of the priests the care of the disordered mind first passed into the domain of medicine with the philosophers of ancient Greece. Pythagoras is said to have employed music for the cure of mental diseases. The order of the day for his disciples exhibits a profound knowledge of the relations of body and mind, and constitutes a most complete system of mental dietetics. The early morning was divided between gentle exercise and reflection, music and study; then came conversation, followed by gymnastic exercises, and a simple and temperate diet; attention to public affairs succeeded, followed again by walking and cheerful conversation, and afterwards a cold bath and supper, with a sparing allowance of wine; and then reading, music, and reflection, concluded the day.

The formation of medical schools in Greece by the disciples of Pythagoras completed the transfer of the sick and insane from the trammels of superstition and priestcraft, consolidated medicine into an art, and, in the department of psychology at least, the philosophy of the Greeks elevated it to the rank of a science. The treatment of mental disorders by Asclepiades, as described by Celsus and Aurelianus, might almost be taken for an epitome of the modern method. "Music, love, and wine, employment exercising the memory and fixing the attention, were his principal remedies. He recommended that bodily restraint should be avoided as much as possible, and that none but the most dangerous should be confined by bonds. He was peculiar in advising that the lunatic patient should be engaged in the self-regulation of his mental powers." (Feuchtersleben, *op. cit.*, p. 36.)

Of the opinions of Hippocrates, the father of medicine, on the subject of insanity, although contemporaneous with Asclepiades, we know less, but yet enough to satisfy us that he was a careful observer of the phenomena of that disease.

The philosophy and the arts of Greece spread to Rome, and the first special treatise on insanity is that of A. Corn. Celsus, which distinguishes several varieties of insanity and their appropriate treatment. Aretæus of Cappadocia describes in graphic terms many additional varieties of the disease, with their causes and prognostics. He and Aurelian both laud the psychiatrical treatment of Asclepiades. Lastly, Galen, with all his learning, appears to have added little to this department of medical observation and treatment.

Over the arts and sciences of Greece and Rome the errors and ignorance of the middle ages gradually crept, until they enveloped them in a vast cloud of worse than Egyptian darkness. The insane, if treated at all, were again consigned to the miracle-working artifices of priests, or else totally neglected. Idiots and imbeciles were permitted to wander about clotheless and houseless, the sport of the wanton and wicked thoughtlessness of children; the frantic and furious were chained in loathsome dungeons, and exhibited for money like wild beasts; the monomaniacs became, according to circumstances, the objects of superstitious horror or reverence; they were regarded as possessed with demons, and subjected either to priestly exorcisms, or cruelly destroyed as wizards and witches; at other times they were made the tools of the designing and ambitious, and, as inspired instruments of the Deity, became the leaders of revolutions and revolts. Vast epidemics of insanity spread over Europe at various periods of the dark ages; lycanthropy, vampirism, the Crusades, the dancing mania, the pilgrimage mania of children, St Vitus' dance, and various other epidemics, followed each other in successive generations. The total neglect or cruel treatment of the insane continued, with little or no alleviation, down to the end of the last century in all the civilized countries of Europe. The revival of learning,—nay, even the reconstruction of medical science,—shed no ray of light upon the unhappy victims of this disease.

During all this period, then, our subject can scarcely be said to have a history. At best it is but the history of scholastic disputations regarding the soul and the supposed humours of the body, or a history of the demonomaniacs of those times, the trials for witchcraft, and the wide-spread massacres which followed; or a history of the epidemics referred to, or of the neglect and cruelty with which the helpless idiots or furious maniacs of all countries were treated.

With the metaphysical speculations of Locke and Leibnitz, followed by those of Bonnet, Condillac, and the Scottish school of metaphysicians, appears to have originated the first impulse to the study of the subject from its purely psychological side. Added to this, came the doctrines of Stahl, which laid the basis for a psychological and practical view of it, which gradually acquired solidity and system from the researches into the anatomy of the brain and nervous system by Soemmering, Reil, Meckel, and Gall. During all this period, however, to which we can only allude, no practical results followed as regarded the treatment of the insane. Public asylums, indeed, existed in most of the metropolitan cities of Europe; but the insane were more generally, if at all troublesome, confined in jails, where they were chained in the lowest dungeons, or made the butts and menials of the most debased criminals. Even in the public asylums, many of which were endowed by the munificence of philanthropists, the inmates were generally confined in low and damp cellars, sometimes isolated in cages or chained to the floor or wall; if harmless, they were huddled together, without regard to their habits, in cells not fitted to contain one tithe of the number immured in them. The medical treatment consisted, perhaps, in an annual bleeding and a few emetics; while the lash was systematically used, justified, and even recommended, as it had been by such authorities as the celebrated Cullen. These unhappy victims of disease were exhibited to the public like wild beasts, and their passions irritated to gratify a morbid and vulgar curiosity. They were often killed by the ignorance and brutality of their keepers, sometimes during rough methods of forcing meat into them, sometimes by barbarous and violent beating.

Such was the state of the insane generally throughout Europe at the commencement of this century; such it continued to be in England so late as 1815, and in Ireland in 1817, as revealed by the inquiries of parliamentary commissions in those years respectively; such it doubtless was also in Scotland, as the report of the commission appointed in 1855, showing the neglected condition of the pauper insane even at the present day, abundantly testifies. Indeed it cannot be doubted that in many countries of Europe the insane are little, if at all, better cared for even now, especially in rural and remote districts.

The greatest step in the amelioration of the condition of the insane originated in Paris with the illustrious Pinel, who immortalized his name by liberating all the inmates of the Bicetre from their chains in 1792. The success attending his philanthropic efforts speedily led to great changes in the treatment of the insane; and his distinguished successor Esquirol endeavoured to extend the same humane principles of treatment to all the asylums of France. One of the earliest institutions of this country to adopt the humane system of treatment was one belonging to the Society of Friends near York, called the Retreat, where, under the auspices of William Tuke, not only were chains, stripes, and cruelty abolished, but the most enlightened principles of moral treatment were adopted. The attention directed to the subject by the published account of the Retreat (1813) speedily led to the introduction of the law of kindness into some of our large public asylums. In the Lincoln Asylum mechanical restraint of every kind was abolished (1836). In the large asylum of Hanwell, Dr Conolly soon afterwards, in spite of many obstacles, succeeded in carrying out the principle of non-restraint with remarkable success; and he has continued to this day to advocate the complete abolition of all mechanical restraint in the treatment of the insane in public asylums, with a devotion and eloquence which has contributed very largely to the adoption of this principle throughout the county asylums of England. The reports of the parliamentary committee (1815, 1816) led to the appointment of a permanent lunacy commission in England, under the auspices of which a number of new county asylums were erected, and in these the principles of non-restraint, and the improved moral treatment of the insane, were carried out and developed. Similar results gradually followed a parliamentary inquiry into the condition of the insane in Ireland (1817). In Scotland the philanthropic efforts of a few individuals led to the erection of several public or chartered asylums in the early part of the century; and in most of these (Edinburgh, Glasgow, Dundee, Dumfries) at an early period, (1840-42) not only was mechanical restraint almost entirely abolished, but a great variety of moral appliances were introduced, such as schools, lectures, concerts, dramatic representations, social entertainments, periodicals written, and in some instances printed, by the patients, excursions to the country, and numerous sources of healthy occupation. If Scotland is still behind the sister countries, in consequence of the want of a legal provision for her insane paupers, she may well be proud of what has been achieved by the spontaneous efforts of the benevolent, and of the admirable manner in which her public asylums have been conducted. In the multitude and variety of the moral appliances for the cure and alleviation of insanity in use in those institutions, she has been in advance of most of the public asylums of either England or Ireland. The hospitals for the insane which have been erected in the various states of the North American republic during the last twenty years, have also been organized and conducted upon the most approved and enlightened principles of modern science: in them everything that can minister to the mind diseased, by distracting it from morbid trains of thought,—the influences of literature, and science, and music, and recreation,—have been added to the salutary regimen and judicious medical treatment of well-arranged and well-regulated hospitals.

Accompanying and assisting in this onward movement we find valuable works on insanity appearing on the Continent and in this country, of which a list is appended to this article. An agent, not less important in the dissemination of all the improved methods of treating the insane, was found in the annual reports of the best public asylums; and of those deserving of especial notice may be enumerated the reports of the Retreat, of Lincoln Asylum, of Hanwell, of the Northampton, Lancaster, Gloucester, and Stafford asylums, and of the Scottish chartered asylums, particularly those of Edinburgh, Glasgow, Dundee, and Dumfries, in all of which the rapid progress of psychological medicine, in its humane and moral aspects, was early and most fully represented. The reports of the excellent county asylums more recently established in England, those of the American asylums, and, lastly, the valuable reports of the Commissioners on Lunacy, have all contributed largely to the spread of the new and improved methods of treatment. Another and important agent in this cause has been the establishment of journals specially devoted to medical psychology. The first of these appeared in Germany in 1806-1808; then followed *Nasse's Journal* (1818–1826); Friedereich's *Magazine* (1829–1838); and, lastly, Dameron and Fleming's *Allegmeine Zeitschrift für Psychiatrie* (1843). In France the *Annales Medico-Psychologiques* (1841); in America the *American Journal of Insanity* (1844); and in England Dr Winslow's *Journal of Psychological Medicine* (1848); and, lastly, the *Asylum Journal* (1853), successively appeared, and continue to be published.

Idiocy.

Special attention to the care of idiots has been a matter of comparatively recent date. The establishment of schools for their education, and the development of their latent or imperfect faculties, first attained considerable success under M. Séguin at Paris. (*Traitement Moral Hygiène et Education des Idiots*, par Edouard Séguin, Paris, 1846.) Dr Gügenbuhl simultaneously (1840) established, under the auspices of the Swiss government, an institution for the *cure* of cretinism at Interlacken, on the Abenberg, where, by commencing their treatment in infancy, it is said that those congenital diseases upon which this condition depends have been cured. The interest excited by the philanthropic labours of this physician has led to inquiries into the condition of idiots in various countries. A commission of inquiry investigated the subject fully in Sardinia (*Rapport de la Commission pour etudier le Crétinisme*, Turin, 1848), where, as also in Austria, Prussia, Würtemberg and Saxony, Bavaria and Baden, institutions for idiots have been established. A careful inquiry, under the direction of Dr Howe, was made into the number and condition of the idiot population in Massachusetts (U. S.), and a school was established there for their benefit. Lastly, in England, at Bath, and afterwards at Highgate near London (1847), and more lately at Dundee and Edinburgh (1855), medico-educational establishments for idiots have been instituted, and promise to confer great benefits upon this interesting and helpless portion of the human family.

In concluding this brief historical retrospect, we cannot refrain from expressing our surprise that the study of mental diseases has been deemed of so little interest or importance hitherto, as to form no part of the curriculum of medical education in this country. Although the large metropolitan asylums afford ample means of illustrating courses of instruction in psychological medicine, the study of the subject has never been required by our licensing medical or surgical boards or universities. Lectures on mental diseases, both systematic and practical, have indeed been delivered in many of the continental medical schools; and of late years, in some of the large asylums of London and in that of Edinburgh, clinical lectures have been given; but attendance upon such courses of instruction is voluntary, with the exceptional case of candidates for appointments in the H.E.I. Company's service, who have been required during the last four years to attend an asylum for the insane for three months. This neglect seems altogether unaccountable, when we reflect upon the many collateral sciences students of medicine are compelled to master, of comparatively little value to them in actual practice, and the many diseases, accidents, and operations, toxicological and analytical investigations, they are carefully and minutely schooled in, which it may never fall to their lot, in a long life, to see or practise; while insanity, which affects 1 in every 400 or 500 of the population, and which, in some of its stages or forms, they can hardly pass a week in medical practice without being consulted about,—often in circumstances requiring great judgment and skill,—is made no part of their medical education at all.

Classification. A variety of methods have been proposed for classifying the different forms of insanity. Without entering into a critical examination of these methods, it may be sufficient for the purposes and limits of this article to give what appears to be a comprehensive and convenient classification, and one as nearly as possible in conformity with the terms in common use among writers on insanity at the present time.

Insanity consists either in a general or partial exaltation or morbid excitement of the faculties, or an impairment of them to a greater or less extent; and we have accordingly three great divisons of the subject,—*Mania*, *Monomania*, and *Dementia*, under each of which there fall to be arranged various modifications, subdivisions, and complications; and, lastly, we have *Idiocy*, consisting in a natural want of development of one or more or of all the mental faculties. The following table exhibits this classification, with the subordinate subdivisions referred to:—

I. MANIA.—*General Derangement of the Faculties.*

Acute	Affecting the emotions and passions only:—*Moral Insanity.* Affecting the intellectual faculties also, *generally*:—*Mania* or *Raving Madness.*
Chronic	
Periodic	
Remittent	

Puerperal Mania.
Delirium Tremens.

II. MONOMANIA.—*Partial Derangement of the Faculties.*

Melancholia	ffecting the desires, emotions, or passions only, without delusion:—*Moral Insanity.* Affecting the intellect or understanding, with delusions, illusions, or hallucinations:—*Intellectual* or *Notiona Insanity.*
Suicidal Mania	
Homicidal Mania	
Kleptomania	
Pyromania	
Dipsomania	
Satyriasis	
Nymphomania	
Monomania of Pride	
... Fear	
... Suspicion	
... Unseen Agency	

III. DEMENTIA.—*Obliteration of the Faculties.*

1st Stage.—Forgetfulness—loss of memory—senile dementia.
2d ... Irrationality—loss of reason—marked incoherence.
3d ... Incomprehension—instinctive stage—fatuous.
4th ... Inappetency—loss of instinctive action—total fatuity.

General Paralysis with *Insanity.*
Epilepsy with *Insanity.*

IV. IDIOCY.—*Non-Development of the Faculties.*

Imbecility.
Idiocy.
Cretinism.

I.—MANIA.

The most striking features of *acute mania* are the exaltations of the emotions, or, as it is commonly termed, the excitement of the patient, the incoherence of his ideas, the restlessness and agitation of his movements and gestures, and the volubility and energy of his language. The invasion of mania is sometimes sudden, and the disease is at once developed by an outburst of violence or excitement. Most frequently, however, it is preceded by some premonitory symptoms, of which the most frequent is the want of sleep; so constant indeed is this harbinger, that a distinguished American writer (Dr Brigham) regarded it as *the cause* of insanity. This sleeplessness is generally accompanied by loss of appetite and derangement of the digestive functions. The patient often complains of headache, confusion, and fear of going mad. He displays irritability of temper and impatience of contradiction or interference. He is unusually active, and full of new projects and ideas. His settled habits become altered; he neglects duties heretofore punctually discharged, or becomes suddenly an attentive observer of duties before neglected. Not unfrequently he uses stimulants to excess, although before temperate in his habits. His affections are altered or perverted; he dislikes his nearest friends, and views all their acts with suspicion and distrust. After these symptoms have gradually manifested and developed themselves during a period of a few days or weeks, he ultimately loses the power of self-control, and his conduct becomes violent, or his ideas and conversation incoherent, or both. In the former case he destroys his clothing, strips himself naked, dresses his naked body fantastically with strips of his blankets, besmears himself with filth, talks incessantly and vociferously, walks up and down, or flings his arms, or tumbles his person about without ceasing. His conversation is characterized by wit, or violence, or obscenity. All these symptoms may exist without any delusions or any incoherence of thought; but on the contrary the individual may display great acuteness, intelligence, and wit, combined with any conceivable amount of excitement, activity, obscenity, and destructiveness. Such a variety of mania belongs, then, properly to that kind of madness called *moral insanity;* the emotions and passions being in a general state of exaltation or excitement beyond the powers of self-control, but without delusions affecting the intellect. Most frequently, however, in a mania, the ideas succeed each other without any apparent order, and the patient raves or talks incoherently. Or some delusion seizes his imagination, and, according to the nature of it, he is affected with extravagant anger, joy, or terror. He is surrounded by foes on whom he seeks to vent his rage; or he is about to be married; or has become heir to enormous riches and to titles of high rank; or he imagines he is a divine being endowed with supernatural powers, and he calls down vengeance on all who oppose him; or he fancies he is surrounded by objects of fear, by fire, and blood, and demons, and he cries out with the utmost terror at the objects of his disordered vision. There may thus, in those cases where the intellect is affected, be only excessive activity of thought, producing rambling and incoherent conversation; or there may be *delusions*—the belief in the creations of the imagination; or there may be *illusions*—the belief that sounds or objects are other than they really are; or, lastly, *hallucinations*, or the actual perception, by the diseased organs of sense, of objects, of persons, and things, and sounds, which have no real existence.

The most essential and characteristic feature of acute mania appears to be the loss of self-control,—1. Over the voluntary acts, resulting in violent and excessive restlessness, walking to and fro, wild, extravagant, bizarre gestures, attitudes, and gesticulations. 2. Loss of control over the feelings, emotions, and passions, which are sudden, impulsive, violent, and varied in intensity and character. 3. Loss of control over the ideas, which appear to succeed each other without any order or law of succession, following neither the laws of association nor those of volition, and being therefore rambling and incoherent. The maniac cannot fix his attention; he hardly sees or recognises external objects; he is carried away by ideal terrors, and is the sport of his own diseased imagination. He confounds time and space, and persons and things, and himself, and is lost in an endless whirl of delirium. There is a total overthrow of the moral sense, the loss of all affection, of all regard to religion, or probity, or decency: even the commonest instincts of nature disappear in the total overthrow of all that is human and natural.

During all this time, however, the patient retains a certain consciousness of self; he may, at least for a moment, be brought to fix his attention and answer a question. After his recovery he may even be able to tell all that passed through his mind, all the delusions and hallucinations that haunted him, the attentions he received, the words addressed to him, and the feelings which influenced him in all his actions.

The countenance is remarkably altered in maniacs: it becomes dark and contracted; the eyes are brilliant, injected, and haggard, and expressive of suspicion,—wandering, but watchful; the sense of hearing is often rendered very acute; the tongue is dry and foul, and the patient is devoured by thirst; the appetite is at one time voracious, and at another seems lost; the skin is dry and greasy, and exhales a disagreeable odour; the cold and fatigue, to which they appear (only) to be insensible, affects them equally with other persons, and they sink exhausted under their own violence and incessant activity, or may die of pneumonia or other diseases if unnecessarily exposed to cold. The pulse is generally small, weak, and frequent; and the excretions diminished or irregular.

The habits of maniacs are very offensive. None are more constant than the tendency to go naked, to tear all articles of clothing, bedding, and furniture, and to indulge in the most filthy and shameless practices and language.

The course of an attack of acute mania is very variable and uncertain; sometimes it is transient, and may not exceed twenty-four hours, or from three to five days. This, however, is rare. A remission frequently takes place within the first week, and after a brief tranquillity a fresh outburst of excitement occurs. The average duration of cases of acute mania has been estimated at six weeks.

Remittent mania.

In some cases a frequent remission continues to take place, followed always, sooner or later, by recurrence of the excitement. These are called cases of *remittent mania.*

Periodic mania.

In other cases these remissions and aggravations occur at regular intervals of time,—every month, every two, three, or six months, or every year; and these constitute *periodic mania.*

Chronic mania.

Again, the maniacal excitement continues with more or less amelioration, but still presenting some of the more characteristic features of mania, such as noise, violence, and destructiveness, for many months, or even years, and is then called *chronic mania.*

The curability of mania has been variously estimated at from 70 to 90 per cent. by different authorities. Although the most alarming and unmanageable, it is the most curable form of insanity.

The recovery is generally gradual, with occasional exacerbations: the patient sleeps, becomes stouter in person, gives up his destructive habits, becomes tidy in his dress, and slowly recovers, sometimes exhibiting a certain amount of reaction in a prolonged depression and want of confidence in himself. Sometimes, though rarely, the recovery is sudden; occasionally it is accompanied by some critical termination, as it has been termed, such as the reappearance of some suppressed discharge or eruption, or the formation of large boils.

If the patient does not recover, the disease passes into some other form,—either into chronic or partial insanity, or more frequently into dementia; or he may die from exhaustion or the supervention of some fatal disease.

Puerperal mania.

PUERPERAL MANIA differs little from the disease described, except in the fact that it is peculiar to females after parturition, and, strictly speaking, occurs within a month after delivery. It has been confounded with hysterical mania, with mania occurring during pregnancy, and with insanity developed after prolonged nursing. But in all these cases the disease more generally assumes some of the forms of partial insanity, and does not differ from such diseases arising from other causes. In puerperal insanity the homicidal impulse is not unfrequently developed; and unless the mother is watched, or the child removed, the offspring may be destroyed by its unconscious and delirious parent.

Delirium tremens.

DELIRIUM TREMENS is another form of mania (*mania à potu—brain fever*), arising from the continued and intemperate use of stimulants. It may be termed a kind of alcoholic poisoning, arising from the accumulation of alcohol in the system. It has also been ascribed to the intemperate use of other narcotics, such as opium. The symptoms are in some respects peculiar. The delirium is generally one of alarm, of fear of robbers and murderers, and is accompanied commonly with hallucinations of vision, and with trembling of the limbs, copious sweating, and tendency to exhaustion. Its course is short, and it terminates either favourably or fatally within a few days; and in some cases, where the immediate danger and violent symptoms are recovered from, permanent lesions remain in some form of partial insanity.

II.—MONOMANIA

Monomania.

Was a term invented by Esquirol to designate cases of partial derangement; the ancient name, *melancholia* being inapplicable, in its modern signification, to those varieties where there was no depression of spirits. The term melancholia (*lypemanie*) he reserved for cases where there was a true melancholy or depression, and monomania for other varieties of partial insanity. As all, however, are cases of partial derangement, all of them may be included under this general term, and we may consider therefore melancholia as one of the varieties of monomania.

The general term monomania implies that the individual is deranged only on one subject, or in reference to one object, or in one particular train of thought or faculty of thinking, and that his intellect, judgment, and emotions are otherwise sound, at least when not exercised on the subject of his derangement. This, however, is not, strictly speaking, true. There are exceptional cases in which persons have appeared to retain all their intelligence and reason, and every mental faculty, in a state of healthy exercise, except in reference to one point; but such cases are very rare, and it is doubted whether, upon a close acquaintance with such persons, we would not discover other points of insanity besides the one prominent and characteristic one. In almost all cases of so-called monomania there are other morbid indications besides the salient one,—morbid dislikes or suspicions, morbid vanity or irritability; sometimes other delusions, sometimes hallucinations of the senses. Still there is generally some one morbid impulse or delusion sufficiently prominent to form the principal and characteristic feature of the case, and to make the name of monomania applicable and convenient, and accurate enough for the general purposes of a classification.

It may be observed further, that almost all cases of partial insanity (monomania) may be referrible either to the category of *moral insanity*, when an emotion, passion, or desire is morbidly excited without any delusion; or they may be referrible to *notional* or *intellectual insanity*, when there are certain delusions. This distinction pervades most of the varieties, and will be illustrated immediately in describing the first variety of monomania.

Premonitory symptoms.

Monomania is always preceded by some premonitory symptoms. Its invasion is seldom, like that of mania, sudden. It is emphatically a chronic affection, compared with mania, and produced generally by the continuous operation of some deleterious influences. In almost every case there exists a hereditary predisposition to insanity, and the attack is preceded by some derangement of the general health;—in some cases it coincides with the development of scrofulous or pulmonary disease; in others it is the result of moral causes affecting the health, such as domestic anxieties, retired and secluded habits, reverses in fortune, disappointments in love or in business. The invasion of the malady is commonly preceded by sleeplessness, by altered habits,—the individual becoming irritable, suspicious, impatient of interference, doing odd things; the wife suspects her husband, or the husband his wife; he neglects his person or his food, or broods over some subject of vexation and anxiety. At length some manifest delusion or some overt act indicates that reason is upset. Some morbid propensity or appetite is developed, or some insane delusion is adopted, corresponding in some way with the previous character of the individual, the exciting cause of the disease, or the more prominent subject of interest for the time.

In mania there is a complete perversion of the character, dispositions, and habits; in monomania the perversion most commonly corresponds in some measure with the previous character, or temperament, or habits of the individual,—the delusion or morbid propensity which is adopted takes its character from the prevailing train of thought preceding the attack, or from the nature of the exciting cause of the disease.

Melancholia attacks chiefly persons of a bilious or melancholic temperament; monomania of self-esteem and pride, those of a sanguine temperament,—the temperament modifying the form of the disease. If the moral causes are of a depressing kind, the delusions and propensities developed assume a corresponding character, and the patient imagines he is ruined—that his soul is lost—that he is about to be executed or poisoned. If the immediate moral causes are of an exciting kind, the resulting insanity is of a more or less gay and elevated character; the patient imagines he has succeeded to large estates or titles, or that he is a person of great power or genius.

The nature of the delusions of the monomaniac is often determined by the more exciting public topics of the day, and their character bears the date of the times. Among the ancients the monomaniacs were prophets and prophetesses, hermaphrodites, or changed in sex, or converted into pigs, foxes, or wolves. In the middle ages the dark superstitions of the times produced many wizards and witches, demonomaniacs and vampires. In modern times it has been observed, that during the first Napoleon's time there were many Napoleons in the public asylums of France. There were many queens in our asylums, and many pretenders to the crown, when our present sovereign ascended the throne. Later years have seen many victims of electrical machines and electricity, of mesmerism, and, lastly, of spirit-rapping, in our hospitals. Instead of furies and demons now pursuing the victims of morbid fears, as of old, it is now the fear of the law, of justice, of prison, of the police, or of being hanged.

Insanity in some of its forms is highly contagious; or rather the imitative faculty, or the strong sympathies existing between morbidly predisposed minds, is so great, that the publication of any revolting murder by a homicidal maniac, or the perpetration of some remarkable suicide, immediately produces a host of imitators. When H. Cornier committed child murder, Esquirol was consulted by many families of distinction, and of all ranks, whose daughters were seized with a similar morbid impulse. When a female committed suicide by leaping from the summit of the Monument, she had so many imitators that it was found necessary to guard the balcony at the top by a cage.

1. *Melancholia.*—The subjects of melancholia are generally of a spare habit of body, have dark hair and eyes, and a brown or sallow complexion. The expression of the countenance is fixed and immovable,—a tension of the features expressive of fear, grief, or despair; the eyes are fixed on the ground, or watching surrounding persons with sidelong and suspicious glances. The pulse is commonly slow and feeble, but hard and thrilling. The skin is dry and hot, with the exception of the hands and feet, which are bedewed with cold perspiration. The sleep is interrupted, short, irregular, and often agitated by dreams and sudden starts. The tongue is white and loaded, the breath offensive, and the bowels constipated. Melancholics are extremely sensitive to external impressions, alarmed by the slightest cause, irritable and impatient of interference. They convert everything into a new source of distress, and dwell without ceasing upon their misery, their fears, and their sufferings. Melancholia may exist as a variety of *moral* insanity, or insanity without delirium. There may be no false belief, no delusion, but a simple abstract gloom, deep and rooted melancholy, an inexplicable but hopeless feeling of wretchedness, a loathing of everything, even of life itself, and an anxious craving for death. The suicidal impulse in some such cases is remarkably strong, and attempts to commit self-destruction are made by every conceivable method, and with the utmost craft and deliberation. In most cases of melancholia, however, there exists some delusion, which seems to be the focus round which the feelings of gloom and horror concentrate. Such is the common belief in eternal perdition; that the person himself has been the cause of ruin and misery to his family; that he has brought judgments and punishment upon the whole human family; or that he has committed the unpardonable sin, and is already suffering the pains of lost souls.

Monomania of fear.

2. Very closely allied to these cases of melancholia are those described as *monomania of fear*, in which the characteristic feature is a constant dread and apprehension of some coming evil,—a foreboding of misery,—a terror of

being hurried away, of being poisoned, or executed, or burnt alive, or of some dreadful and unavoidable calamity.

Such delusions are sometimes not incompatible with the discharge of the ordinary duties of life. The celebrated Robert Brown, at the time when all the powers of his mind were in full exercise, believed that his soul was annihilated, and that instinct only, common to him and the brute creation, was left to him. Cowper the poet believed that he alone of all human beings was excluded from the vicarious merits of our Saviour's sufferings.

Suicidal mania.

3. These two varieties of monomania are those most frequently accompanied by a disposition to commit suicide. Sometimes this impulse is a morbid impulse, unaccompanied by any delusion,—a loathing of life, a craving for death, an irresistible impulse to commit self-destruction. This must be regarded as another form of moral insanity, and may be termed *suicidal mania.* Most frequently, however, this fatal propensity seems to originate in the dreadful delusions of the patient, in the despair arising from the conviction of being ruined or eternally lost, or in morbid apprehension of some approaching and horrible calamity.

Not unfrequently these, as well as other varieties of monomania, are associated with hallucinations of the senses; the persons affected hear voices threatening them with their approaching doom; or they see objects of terror, visions of departed friends, or of demons; or they taste poison in their food, or smell the sulphureous vapours of the bottomless pit, of which they believe they are already the hopeless inmates.

Monomania of unseen agency.

4. Allied to these forms of partial insanity are those cases which has been described as *monomania of unseen agency.* Founded, perhaps, upon some morbid sensations caused by flatulence or neuralgia, the unhappy victims of the disease believe that they are the sport of some mesmeric or electrical operations; that gases are injected into their system; that they are subjected to some strange influence during sleep; that persons at a distance control and act upon them, and even strike them; or that some person is actually in the inside of their body, and sways their feelings and actions according to his own will.

Monomania of pride, vanity, &c.

5. Very different, indeed, in their external manifestations and general deportment are the cases of monomania in which the sentiments of self-esteem, pride, veneration, and love of approbation, are morbidly exalted. The delusions under which such monomaniacs may labour are as varied and as numerous as the objects which stimulate to ambition. One may imagine himself endowed with exalted genius,—he is a poet, or philosopher; another, a distinguished musician or vocalist, although able to produce only the most dissonant sounds from his favourite instrument, or to scream in wretched discord with it; another believes he is a royal or divine personage, or a prophet, or endowed with supernatural powers, able to cure diseases, to regulate the fate of empires, or to command the sun; another believes that he has discovered some infallible cure for all human miseries, that he is about to convert all mankind and make them supremely happy; another, that he can direct the elements and give rain, sunshine, or storm; another is possessed of enormous wealth, and has paid off the national debt, and is about to build palaces and endow numerous institutions for the public good. There is, however, in such persons no loss of the idea of personal identity; they are still John Smith, or James Johnston, or Thomas Brown; and they are capable of acting with the utmost want of consistency of character,—performing the most menial acts, or working industriously at some trade or domestic duty.

In some cases a morbid vanity amounts to folly or madness without delusion; and indeed any of the sentiments, passions, or desires may be exalted into morbid action without delusion. In such cases the conduct of the individual may expose him to ridicule or pity, and he may be looked upon as a harmless, half-witted creature; but he may buffet his way through life, supported by his own self-importance, and escape the restraints which society imposes upon the morbid exercise of passions or propensities when they interfere with the comfort, happiness, or safety of others.

Klepto-mania.

In other cases the overt acts of the individual may endanger his own personal safety, may lead to the profuse and foolish expenditure of his means, or may exceed the limits which society deems tolerable; and he then becomes the object of treatment or surveillance, or even of confinement. To a morbid and ridiculous vanity such persons very often unite other depraved and morbid propensities. Of these, the most frequent, perhaps, is the practice of lying, and the art of deceit. A propensity to steal and hoard every article that can be surreptitiously appropriated is not an uncommon symptom in cases of this kind of moral perversion. This propensity to steal sometimes exists as a distinct form of monomania, without any other very obvious departure from sanity in the general state of the mind or conduct. It has been called *kleptomania.* The propensity has sometimes been exhibited by persons in the better ranks of life, who had no motive to steal, but could not resist the incontrollable impulse to purloin on all occasions. It is generally, however, one of the symptoms only of other forms of insanity, and of none more frequently than of those cases of moral perversion just described.

Pyro-mania.

The propensity to tear and destroy, which is so constant in mania, sometimes also, in a minor degree, accompanies partial insanity; in other cases the propensity to set fire to things, described as a special variety of monomania, under the name of *pyromania,* is a characteristic feature, and in some instances, it is said, is the sole morbid impulse.

Of all the symptoms of insanity, those referrible to altered affections, perverted desires, and morbid propensities, are the most constant; and delusions ought rather to be regarded, like hallucinations of the senses, as the accidental concomitants than as the essential features of insanity. In a large proportion of the cases of partial insanity in particular, the grand and distinguishing feature of the disease is, that the *conduct* of the individual is irrational or insane,—different from what it used to be, or from that of other people; or that his tastes, affections, habits, and propensities are *changed,* and no longer regulated, as they were wont to be or as others regulate them, by a due regard to personal welfare and the settled opinions of society. He does things which very often his own reason and conscience revolt at,—things which he deplores and cannot help doing.

Such moral perversion is not unfrequently met with in young persons, and is sometimes associated with some natural peculiarities of character, such as inability to acquire certain elements of education, disregard to personal cleanliness, or the pride, natural to all children, of being well dressed. At an earlier or later period of youth, sometimes about the age of puberty, this moral perversion is developed. The person becomes irrascible, passionate, vindictive, and dangerous; often violent without provocation; sometimes destructive of clothing or furniture; sometimes mischievous and cruel; at other times disposed to wander from home, without object or plan.

Satyriasis and nymphomania.

In persons who have passed the age of puberty this disease sometimes affects the sexual desires or propensities, and is indicated by gross obscenity of language, by licentious and lascivious looks, and acts of the most disgusting kind. This disease, if not a symptom only of other forms of insanity, is called *satyriasis* in the male, and *nymphomania* in the female. It is sometimes a symptom of some serious organic disease of the brain.

In other cases, and these not a few, in this country, the incontrollable impulses of the patient lead him into habits of inordinate drinking; and persons exhibiting those constitutional peculiarities described, not unfrequently display great violence when under the influence of intoxicating liquors—becoming furious and dangerous.

In many of the cases of the kind of moral insanity which are referred to, the principal, and, indeed, in some the sole feature, is an incontrollable craving for stimulants, and the indulgence in them to an extent ruinous to health, and happiness, and every hope in life. It is difficult to distinguish this disease from mere drunkenness; but it is unquestionable that there is a diseased condition of the nervous system, whether constitutional or the result of habit, or partly both, in which the individual drinks without any self-control, in which he cannot control himself, and is therefore a proper object for control, protection, and treatment on the part of others.

Oinomania.

This disease has been termed *dipsomania* by some authorities, by others *oinomania*. Both names are inexact: it being neither a thirst, as the first implies, nor a thirst for wine exclusively, as the second signifies, but a craving for any kind of narcotic stimulants. It is more proper to regard it as one of the varieties of moral insanity, of which this craving for stimulants and insatiable use of them is one of the principal symptoms. It is perhaps in few instances the only symptom. The disease is generally hereditary, and it will be found that the father, mother, or some other near progenitor, has suffered from it. It is very generally associated with a total disregard to truth. Such persons, particularly females, are singularly mendacious. They will resort to every possible device to procure stimulants, to excuse their conduct, to deceive their friends; they generally utterly deny their habits, and display a fertility and ingenuity in deceiving themselves and others which is truly remarkable. This disregard of truth is very often associated also with a great deal of self-esteem and inordinate vanity. Such persons do not drink from the pleasures which the social board affords, but, on the contrary, in company will often preserve a certain amount of decorum. Neither do they drink for the pleasure which the wine gives them, for in the absence of their favourite beverage they will have recourse to any substitute. They labour under an incontrollable craving, and drink because they cannot help it. No considerations of self-respect, no regard to domestic ties, to religion, to the certainty of ruin, shame, or even death, can prevent the individual drinking until he can drink no longer. He sees his impending ruin; deplores his fatal impulse, his inability to control his desires; and will assert with tears, that if hell were yawning on one side of him and a bottle of brandy standing at the other, he could not resist the impulse to drink, although the next moment he were to be precipitated into the gulf beside him. Such persons are now generally regarded as no longer responsible agents,—as insane,—and requiring, therefore, to be constrained and protected against themselves. Our asylums contain many such cases, although some degree of uncertainty prevails regarding the length of time they may be subjected to control; and the want of some legal enactments regarding them is much felt and complained of.

This disease sometimes assumes an *acute* form; and originating in some accidental cause, a constitutional change, or debilitating attack of disease, affects a person of temperate habits and predisposition; and in such cases is, with proper care, generally recovered from. Sometimes it assumes a *periodical* form; and persons have been known, distinguished as merchants or men of professional or literary reputation, who have been subject for many years to periodical attacks of insane drinking. But the most hopeless form is when the disease is *chronic*,—when it has been slowly engrafted upon a constitution hereditarily predisposed to it by systematic indulgence in intemperate habits. Several of our most attractive authors, men of singular and varied genius, have gradually sunk under this disease. One of the most noted of recent illustrations of this state is perhaps afforded by Edgar Poe, the American poet, whose whole life evinced that he laboured under moral insanity. Poor Charles Lamb, who played cribbage to amuse his demented father, and periodically conveyed his weeping sister to an asylum, was, by his own confession, for many years of his life, while he was writing to an admiring circle of readers, but a melancholy wreck, passing one-half of his time in the most wretched distress, and the other half in miserable imbecility.

Monomania of suspicion.

One of the most constant and salient features of insanity is the *suspicion* which forms a prominent symptom in a vast number of cases of all kinds. It is common both to mania and monomania. Even when the mind is carried away by a torrent of emotion or passion this is observed very generally as a marked trait among other symptoms. The patient watches every movement of his friends or medical attendant; suspects they are plotting against him; that he is supposed to be mad, and that some one is about to carry him off to an asylum; or suspects his food is drugged or poisoned. Not unfrequently one of the first indications of insanity is the idea entertained by the patient that every one he meets is looking specially at him; that the clergyman preached at him; that there is some plot of which he is the object. What is thus common to most varieties of insanity comes to be the principal feature in many cases of monomania: some suspicion regarding some person or subject occupies the mind and fills it with apprehension, while the faculties remain comparatively sound in reference to other subjects. Such cases have been designated *monomania of suspicion*.

This variety of monomania is not unfrequently associated with feelings of enmity and a desire of revenge against the perpetrator of the fancied injuries under which the patient suffers. In some cases the vindictive feeling is overpowering, and leads the patient to some dreadful deed of vengeance. These are the cases of insanity which are most dangerous to society. It was by such a monomaniac that the Hon. Spencer Perceval was shot in the lobby of the House; and from such another Mr Drummond met a similar fate, by being mistaken for Sir Robert Peel. (See the works of Georget, Esquirol, Marc; Prichard *On Insanity*; Simpson *On Homicidal Insanity*, &c., &c.)

Homicidal mania.

The propensity to kill, although generally stimulated into exercise by the belief in some imaginary wrongs, is sometimes an abstract impulse without motive,—a morbid craving for blood,—an irresistible impulse to destroy. This constitutes another variety of *moral insanity*, and one which has been generally repudiated in our courts of law as a defence for homicidal acts. That this *homicidal mania* is a real disease, in which the patient is carried away by the incontrollable impulse of a morbid propensity, is established by a large array of cases. The most noted illustrations of this morbid state are those horrible tragedies so frequently recorded in the newspapers of a father or mother deliberately destroying their own offspring. Very often this homicidal impulse is accompanied by a strong effort to restrain it, or to save the victim of it by some timely warning. Such persons have begged to be restrained, to prevent them committing murder; or have called out to their friends to save themselves by flight, before they expended their last effort at self-control.

Monomania of superstition.

Religious madness, as it was called, at one time occupied a large space in works on insanity. It may with greater propriety be called *monomania of superstition*. The subjects of it are generally profoundly ignorant of true religion. They are inspired by fanatical excitement or superstitious fears. One regards himself as a divine personage,—as the Saviour again incarnate,—and is prepared to be immolated for the sins of the world. Another is inspired with the prophetic spirit, and denounces curses upon all around as the worst of sinners. Another is the woman described in the Revelations, who is to give birth to a man-child. Or, again, we find others possessed with demons,—Satan himself,—accursed of God and man: the *demonomania* of former ages.

Demonomania.

Such are the most frequent forms of partial insanity, arranged conventionally, and perhaps accurately enough for practical purposes. But there are innumerable cases which it is impossible to reduce to any classification, where the patient is insane in reference to one particular fact, and not in a faculty or train of thinking. Of such cases are those where persons have imagined themselves cocks, grains of wheat, pumps, pairs of shoes, a half-crown, made of glass or of gold; where men have believed themselves pregnant, and women have believed themselves men; and innumerable other fancies, which might be mentioned were it not that they are as numerous and varied as the fancies which the human imagination can conceive.

III.—DEMENTIA

Dementia.

Consists in impairment or obliteration of the mental faculties,—in a diminished activity of the mental operation, either general or partial. In mania and monomania there is an excessive activity of some feelings, or emotions, or faculties,—a disturbance of the equilibrium of the mind: in dementia there is a mental asthenia, an impaired action, a moral atrophy. This impaired activity may vary from the smallest appreciable weakness to the total loss of all indications of thought, consciousness, or volition,—to complete fatuity.

Dementia is most frequently the sequel of other diseases. It is the most frequent termination of mania or monomania when not recovered from, or may follow apoplexy or repeated attacks of epilepsy; although it is not unfrequently the original and sole form of an attack of mental derangement.

In demented persons external objects are generally viewed with little or no interest, and they appear to be imperfectly appreciated. Hence, perhaps, the impaired power of reasoning, or comparing, or perceiving the relations of things; hence, too, probably the loss of memory, which is a principal feature of dementia. The objects or events around being observed with little or no attention, make no impression on the mind, and are immediately forgotten. Such persons often retain a lively recollection of the events of their childhood, and of everything connected with their history up to the period of their insanity, and yet are totally forgetful of all recent events; so much so, as very often not to remember that they have seen their husband, wife, or children, although visited by them only a few moments before.

In most cases of dementia, along with this impaired memory there is a marked incoherence. The ideas appear to pass through the mind as in dreams or in reverie, without any effort to direct them in a particular channel, without any apparent connection or sequence, such as takes place in the active operations of a healthy mind. Very often such persons repeat words or sentences without attaching any meaning to them; they talk as if they were thinking aloud, or rather as if they were not thinking at all, but merely repeating by rote a series of old forms of speech, or words associated together by their sound rather than their sense.

The activity of the emotions and passions is altogether destroyed, except when, as occasionally happens, a brief paroxysm of excitement lightens up the drear monotony of their stupor. In general they have no desires, no aversions, no hatreds, no affections; they are docile and passive; they have no will of their own; they spontaneously determine no act; they passively obey the will of others; receive the visits of their friends without pleasure, and part from them without regret; they are insensible to all the griefs and pleasures which affect others; at times they laugh at some passing thought, and at others cry, as children laugh or cry in their sleep according as their dreams are pleasant or painful.

Their movements are peculiar: some will walk up and down incessantly; others will dance for hours together, performing some monotonous movement continually repeated. Others, again, will sit for days, weeks, months, or even years, in the same corner, crouched up in the same attitude. Some will repeat incessantly the same words or the same phrase night and day; others will preserve a uniform and unbroken silence. Some clothe themselves in a ridiculous way, and, if permitted, will adorn their persons with a variety of absurd ornaments.

The face is generally pale; the eyes watery; the looks wandering, or fixed on vacancy; the countenance destitute of expression; the body lean and emaciated, or at other times loaded with fat.

The functions of organic life are performed with regularity; the sleep is commonly profound, and the appetite voracious.

Dementia is a rare disease in young persons, unless when complicated with epilepsy, and is most frequently either the termination of other forms of insanity or the accompaniment of advancing age. The varieties may be conveniently referred to different stages or degrees; and in the table of classification we have given the four degrees distinguished by Dr Prichard; namely, 1. That of forgetfulness, or loss of memory; 2. That of incoherence, or loss of the power of reasoning; 3. Incomprehension; and 4. Inappetence, or total fatuity.

Dementia is less curable than most of the varieties of insanity already described. Occurring in young persons, arising from removable causes of a debilitating kind, and occasionally when the result of mania, it may be removed by proper treatment; but a majority of the cases of this kind of mental derangement are very hopeless.

The duration and termination of uncured cases of dementia are very variable. When it is connected with serious diseases of the brain or of other organs, such as the lungs, it may terminate fatally within a short period, but if not so complicated, the patients may prolong their existence to nearly the average term of human life.

General paralysis.

General Paralysis of the Insane.—The insane are more liable than others probably to paralytic attacks; but the disease called *general paralysis* is one of a special character, and may be viewed either as a variety of insanity complicated with a peculiar affection of the motor powers, or as this affection of the motor powers complicated with insanity. The disease was first described by Esquirol and other French *alienistes*, but is now generally known, at least in all large asylums, in this country.

The characters of the mental disease which accompanies this affection are generally so peculiar and distinctive as to have acquired for it the name of *Mania paralytica*. The individual imagines that he is possessed of great wealth, and he is full of projects involving the expenditure of enormous sums of money; he believes that he is possessed also of titles and dignities of the most exalted kind; and, in short, all his delusions are of the most extravagant character (*delire ambitieux*). Conjoined with this there is generally a remarkably facile disposition, so that the patient is easily coaxed and managed. The mental disease is not always of this description; occasionally, but rarely, it presents the features of melancholia or monomania, and generally after a few months, when the violence of the first attack has subsided, it passes into dementia, which gradually increases and deepens until the fatal termination.

The peculiar general paralysis sometimes precedes the development of mental changes, but more frequently coincides with them, or is gradually developed after a maniacal attack. The first symptom is commonly a difficulty in articulating distinctly when speaking. The speech is "thick" or mumbling, like that of a person intoxicated. Next, although sometimes first, the powers of locomotion become impaired, and the person walks unsteadily, balancing himself with difficulty, like a drunk man. This loss of power, or rather of *control* over the muscular movements, gradually and slowly increases until the patient is unable to walk without assistance, cannot speak at all, and can scarcely swallow even liquids.

Patients labouring under this disease are generally subject to attacks of stupor or insensibility, with convulsions somewhat resembling epilepsy. Such attacks in some are frequent and severe, and in others are seldom or very slight.

The disease is regarded as incurable, and death generally takes place within one or two years. The fatal termination sometimes occurs during one of those epileptiform attacks to which the patients are subject; more frequently it is due to the development of other diseases, such as consumption or diarrhœa, or to the gradual exhaustion which accompanies the progress of the affection, accelerated not unfrequently by the formation of bed sores.

Epilepsy.

EPILEPSY WITH INSANITY.—Epilepsy, or the falling sickness, has been known from the earliest ages, and from the terrible character of the symptoms, it was ascribed by the ancients to demoniacal possession or to the anger of the gods. When it attacks young persons and continues to affect them, it appears to arrest the development of the brain, and to produce a permanent imbecility. Persons of maturer years who are subject to frequent epileptic fits have a tendency gradually to become affected by some variety of insanity. Sometimes it assumes the form of mania, maniacal attacks supervening upon the occurrence of the epileptic fits. These maniacal attacks are of short duration, generally passing off in a day or two, but are very frequently characterized by extreme violence. Indeed, maniacal epileptics are the most dangerous of all insane persons; their fury is blind and impulsive, and no control or fear daunts them.

Epileptics are also subject to various forms of monomania, and not unfrequently suffer from hallucinations of the senses.

The most frequent effect, however, of continued epilepsy is the gradual impairment of the memory, of the sensibility, and intelligence, until the subjects of it fall into a complete state of dementia.

The tendency to dementia appears to bear a direct relation to the frequency and persistence of the epileptic fits.

Epilepsy with insanity is generally regarded as incurable, and the principal object in the treatment of the patients is to guard them against the dangers incident to the fits;—to prevent them falling upon sharp corners, or into the fire; or dying of suffocation by turning over on their face upon the pillow during a fit; and to secure them and others from injury during the delirium or violence of the accompanying mental derangement. In the intervals between their paroxysms many of them are active and industrious, and make themselves useful and agreeable; and it seems well ascertained, that by judicious management, good diet, suitable occupation, and freedom from all causes of excitement or irritation, the frequency and violence of their attacks may be very much diminished.

Pathology.

The morbid appearances found in the bodies of those who have died insane are not such as to afford a satisfactory explanation of the symptoms of the disease. Changes indicative of a slow inflammatory action in the membranes of the brain are more or less frequent. Effusion of fluid beneath the membranes and into the ventricles or cavities of the brain is also a very frequent occurrence. These appearances are, however, very varied in their frequency and extent, and are sometimes found in the brains of persons who have not been insane. It is therefore inferred that they are the accidental concomitants of other morbid changes not yet recognised. Our ignorance of the minute anatomy of the healthy structure of the brain, and of those changes in its condition which accompany the exercise of its functions, make it probable that we are yet unable to appreciate by our means of observation those morbid changes which are the cause of mental disease. Some authorities have contended that insanity is a disease of the blood, and that the absence of pathological appearances in the brain, and the analogy between insanity and the effects of alcohol and other poisons which act upon the brain through the blood, afford strong presumptive evidence in support of this hypothesis. Others, again, have maintained that in those cases where no morbid changes have been found in the brain, the mental disease has been symptomatic of some other bodily affection, such as disease of the liver, bowels, or uterus. Lastly, in general paralysis of the insane the morbid changes generally found are more constant, such as thickening and opacity of the membranes of the brain, and effusion of serous fluid; and along with these, softening of the gray matter of the brain, and enlargement of the nucleated cells which enter into its composition. In not a few instances the white matter of the brain is increased in firmness and density. The large quantity of serous fluid found in the cavity of the cranium in many cases must be accompanied by a corresponding diminution of the size of the brain; and it appears also to be determined that the brain undergoes an increase in weight and in its specific gravity during the progress of the disease.

Causes.
1. Predisposing.
Hereditary predisposition.

The predisposition to insanity, it is well known, is engendered by marriages between blood relations. The children of cousins-german are, according to common observation, frequently of imbecile mind, idiots, or predisposed to insanity; and when intermarriages are confined within a limited channel during successive generations, they lead to the production of a greatly deteriorated, scrofulous, imbecile, and insane family.

Besides marriages between blood relations, there are other causes affecting the parents which appear to have an influence in engendering a predisposition to insanity in the offspring. Of this kind are strong mental emotions, hysteria, insanity, over-exertion of the mental faculties, and bad health on the part of the mother, and, perhaps, more frequently than any other cause, excess in the use of wine or other stimulants. Guislain states that he has known a whole generation of lunatics born of a mother who was habitually intoxicated for a series of years, although neither she, her husband, nor any of their families, were predisposed to insanity. He has also known epileptic children born of drunken parents, neither of whom were epileptic or predisposed to disease of the brain.

It is believed that the children of parents advanced in life are more liable to insanity than others; and that any causes which may produce nervous debility on the part of one or both parents tends to produce imbecility or a predisposition to insanity in the offspring.

It may be observed that among the children of parents predisposed to insanity there are remarkable peculiarities; one perhaps is an idiot or imbecile, another is a great libertine or drunkard; one may be distinguished by genius of a particular sort, while another is extremely reserved and secluded in his habits; one is a poet, and another a religious enthusiast; in fine, there are peculiarites and eccentricities which distinguish one or more members of the family in which hereditary predisposition to insanity exists.

The hereditary predisposition is frequently developed at a particular age in successive members of the same family, and father and son, or mother and daughter, will become insane at the same period of life.

The predisposition also is generally to the same form of insanity in successive generations,—father, son, and grandson become maniacal or epileptic,—mother and daughter have puerperal mania,—a parent and a whole family of brothers and sisters die of delirium tremens; and of all facts of this kind, nothing is more remarkable or more constant (according to M. Falret) than the constancy with which the suicidal impulse is transmitted from parent to child. A grandfather, a father, and son, have been known to destroy themselves at the same ages and in the same manner.

In consequence of the dislike which exists among most families to admit that there is any insanity or scrofula in their blood, it is extremely difficult to arrive at correct conclusions as to the frequency of hereditary predisposition to this disease in those affected by it; and accordingly we find the hereditary tendency variously estimated by different writers: by Parchappe, *e.g.*, it is estimated at 15, by Guislain at 25, by Webster at 33, by Thurnam at 34, by Esquirol at 45, by Jessen at 65, and by Holst at 69 per cent.

Lastly, M. Baillarger and Dr Browne deduce from their observations that the predisposition is more frequently transmitted through the maternal than through the paternal side of the family.

Age.

The predisposition to insanity appears to increase gradually with advancing age, being in infancy and childhood very small, and in extreme old age, if we include *senile dementia*, very great. From an extended series of statistical records, it appears that insanity is most frequent between the ages of thirty and forty. Next in frequency is the decennial period between twenty and thirty; and then comes the period between forty and fifty. These results do not, of course, give the number of insane of each age relative to the entire number of the population alive at that age, but only the absolute numbers affected at each decennial period. Making allowance for the successively decreasing number of persons alive at each successive period of life, it may be stated that, with the exception of the first period named, insanity, including dementia and fatuity, becomes more and more frequent with advancing age.

Sex.

Neither sex appears, on an extended view, to be more predisposed to insanity than the other. In some countries and in some districts the frequency of insanity in one sex is much greater than in the other; thus, in France the proportion of insane females to insane males is as 14 to 11, and in Paris as 3 to 2; on the other hand, in Great Britain and Ireland, and in Norway and America, the relation is reversed, the insane males being in the former as 13 to 12, in Norway as 6 to 5, and, taking the states of New York and Connecticut alone, as 2 to 1. These remarkable differences probably depend upon accidental circumstances, such as the greater frequency and poignancy of the *exciting* causes affecting the opposite sexes in these countries, than upon any greater predisposition to the disease in one sex as compared with another; for in collating the available statistics of all civilized countries, Esquirol arrived at the conclusion that the insane males were to the insane females in the ratio of thirty-seven to thirty-eight,—a very inconsiderable difference taking into account the difference in the actual numbers of each sex in the population.

Temperament.

The influence of *temperament* appears rather to determine the form of insanity than to predispose to the disease in one temperament more than another. Persons of a melancholic temperament are more predisposed to melancholia than to other forms of insanity; the lymphatic temperament predisposes to dementia; and the sanguine temperament to acute mania, with great violence and excitement where the temperament is specially pronounced.

Previous attacks.

No cause predisposes more certainly to insanity than previous attacks of the disease, however occasioned. Exposure to the same influences which developed it before will almost certainly lead to its recurrence. The frequency of relapses, as shown by the statistics of asylums, is very great.

Education.

Defective education, over-stimulation of the intellect at an early age, the early indulgence in strong passions and sensual propensities, the neglect of the cultivation of the will, of habits of self-control and self-denial, particularly in mental constitutions naturally ill-balanced, conduce in the greatest degree to the development of a predisposition to mental disease.

2. Exciting causes.

The exciting causes may be either moral or physical,—the former being those which affect the mind directly; the latter such as affect the body first, and through it the mind. It is believed that the moral causes are more frequent and efficient in the production of insanity than the physical. Of this it is believed the greater frequency of mental diseases among highly civilized communities than among barbarous or semi-barbarous nations, affords a strong proof. In uncivilized countries the habits are uniform,—there is the same invariable routine in the domestic history, in the manners, customs, and social institutions. In highly civilized states, on the other hand, where every department of life is full of competition, strife, and activity, the anxieties of living are innumerable; and there is a constant change of customs, of the position in life of individuals,—some rise to fortune, while others suddenly sink to ruin. The political and religious controversies which agitate the community; the arduous pursuits upon which numbers enter, stimulated by avarice or ambition; the race after fame; the jealousies and rivalries of parties; the intrigues of private life; domestic griefs and anxieties, caused by jealousy, misfortunes, and poverty;—are a few of the causes which may serve to account for the extreme prevalence of insanity in the European and North American states. In the tents of the Arabs, the huts of the Indians, and among the savages of Africa and the islands of the Pacific, insanity is said to be unknown. In Nubia and Abyssinia travellers failed to trace it. The insane in the asylums of Cairo and Constantinople are an insignificant portion of the population. In China we are assured it is very rare. The following table, constructed from various sources, shows its frequency in some of the more highly civilized states compared to the population:—

	1 in each
In Italy	4879
... Rhenish Provinces	1000
... France	1000
... Westphalia	846
... Belgium	816
... United States	721
... England	578
... Denmark	549
... Scotland	370
... Norway	329
... Iceland	311

It is difficult to account for the great frequency of insanity in the countries last mentioned, unless it be due to the scanty nature of the population, their miserable means of subsistence, and the greater frequency of intermarriages.

Moral causes.

Pinel estimates the frequency of moral causes, compared with physical, in the production of insanity, as 464 to 219.

The most frequent of all the moral causes are domestic griefs, anxieties, and reverses in fortune. Next in frequency are violent emotions and passions, disappointments in love, grief for the loss of relatives, and wounded ambition or pride.

It is inferred from statistical tables, that married persons are less liable to insanity than unmarried.

Religion was at one time supposed to be a frequent cause; and it might be inferred that a subject calculated to inspire, on the one hand, vivid emotions of happiness, or gloomy forebodings, terror, and despair on the other, would be likely to exercise an important influence on persons predisposed to mental disease, when their minds were absorbed with such feelings. Nevertheless, as a cause it is by no means frequent. Many of the cases ascribed to it are due rather to ignorance and superstition; while most of the cases of religious despondency are due to other causes very often affecting the bodily health.

Physical causes.

By far the most common in this country of the causes of a physical kind is intemperance. Next in frequency is general derangement of the health, particularly of such a kind as exercises a debilitating effect on the body and nervous system. The critical period in females, parturition, and uterine irregularities; blows on the head and diseases of the brain, epilepsy and advanced age, fever, intestinal worms, the suppression of an accustomed discharge or eruption, the metastasis of rheumatism or gout, and various vicious indulgences, are, nearly in the order enumerated, among the most frequent of the other physical causes to which insanity has been ascribed.

Treatment.

The medical treatment of the insane has undergone a great revolution during the present century. At one time large and repeated bleeding was much lauded in the treatment of mania. It is now almost entirely abandoned, and regarded as dangerous to life, or tending at best to convert the case into one of dementia. The general use of blisters and issues, of purgatives and emetics, and of specifics, once in high favour, has now also given place to the use of milder remedies and more rational principles of treatment. It would be out of place to enter into details in this article as to matters purely medical; but it may be stated in general terms that the warm bath, and especially prolonged warm baths with cold applied to the head, have been found of great advantage in allaying the excitement of mania; that the judicious use of opium in certain cases, for procuring sleep, has also been esteemed as a valuable remedy; and that the restoration of the general health by the use of appropriate means, and the removal of local diseases, when they exist, by treating them on the general principles of medical science, constitute nearly all the canons of medical treatment now recognised in regard to mental diseases. It is not now imagined that any particular medicine exerts a specific effect in the cure of insanity; and beyond the judicious and skilful treatment of the patient with a view to the cure of local bodily disease, and the restoration of the whole system to the standard of robust health, the great and important part of the management of the insane consists in what has been called the moral treatment.

Moral treatment.

The great principle upon which the moral treatment of mental diseases is founded is the distraction of the mind from morbid trains of thought or feeling, and its occupation in new and healthy channels. In carrying out this principle, the first and most important object is to remove the patient from the scene of his first attack, and from the presence of his friends. The objects which surround him suggest and preserve in activity the subjects of his excitement or delusion; the presence of friends exerts the same deleterious influence, and as they are commonly with the insane the special objects of dislike and suspicion, their presence irritates and aggravates the disease; while they commonly add to the injury they are thus unconsciously inflicting, the evil of deepening and strengthening all the morbid fancies of the sufferer by vain efforts to reason him into a belief of their absurdity. "Dr Willis," says Esquirol, "who acquired so great a celebrity by having assisted towards the happy termination of the first attack of madness experienced by George III., unfurnished the king's apartments, dismissed his courtiers and domestics, and had him attended by strange servants."

The complete manner in which this change of scene and associations is effected by removal to an asylum, is one of the principal causes which renders early removal to such an establishment an efficient curative agent.

The patient requires to be surrounded by experienced attendants, allowed the greatest liberty, and treated with the utmost amount of kindness compatible with his own safety. All restraint should be avoided; the free use of his limbs, and abundant exercise in the open air, tend to carry off the superfluous energy and excitement of his malady.

A variety of means may be had recourse to, suited to the peculiarities of each case, for carrying out the first principle of treatment,—the healthy occupation of the mind. Of these, useful and rational occupation, particularly in the open air, holds the first rank. Walking, gardening, open-air games, travelling, angling, and other such like amusements, according to the rank, or taste, or disposition of the patient, are next to be preferred. In many cases music exercises a soothing and salutary influence. In others, drawing, and in-door games of all kinds, combined and varied with reading, sewing, knitting, embroidery, and other occupations suited to the peculiarities of the individual. In a large proportion of cases the regulated observance of religious exercises, and attendance upon divine service, contributes to the healthy moral influence of other agents. In fine, everything which can employ and interest a healthy mind, and which is apart in its character or by association from the morbid thoughts of the patient, ought to be brought into exercise for his recovery. These various agents, however, must be judiciously adapted to each case, and must be systematized and directed with prudence and skill, and a constant attention to the great object of establishing a healthy current of thought and feeling through the channel of regulated habits, occupation, and amusement.

These appliances for the treatment of mental diseases are best carried out in a well-managed asylum, where every thing is organized with a view to their development, and directed and superintended by a skilful and experienced physician. The treatment of the insane in private dwellings, even where the most lavish expenditure of money can be commanded, cannot in general secure the same advantages. The patients are exposed to the unkindness or neglect of mercenary and eye-serving attendants, who soon weary of duties which are both trying and onerous if not under the constant supervision of a controlling and directing power.

The arrangements and management of some of our best regulated asylums give at one view the best idea of the proper treatment of the various forms of insanity. These institutions, compared with those of former years, stand out in bold relief as monuments of the progress of the age; and to those whose ideas of insanity are associated with ferocity, danger, and all that is loathsome, they must appear to be among the wonders of modern times; so much has been effected in them by well-directed discipline and enlightened philanthropy in ameliorating the condition of the insane.

Such a house subserves a variety of ends: it is a place for the isolation and safety of the dangerous; it is a retreat and home for the hopeless and incurable; it is a great hygienic hospital for the restoration of the insane to physical and mental health; a house for moral and physical education; it is also a school for elementary, artistic, scientific, literary, and religious education; and an industrial establishment where the busy crafts of artizans and gardeners, and all the homely occupations which can employ the hands and heads of men and women, are called into systematic and daily activity.

The best institutions of this kind are erected on carefully selected sites commanding a wide prospect of cheerful and varied scenery. They are placed in sheltered positions, with a southern aspect, and are inclosed within an ample space of garden and farm. The beneficial influence of cheerful and picturesque scenery upon the minds of the insane is unquestionable; and the occupations afforded by a farm, by flower-gardens, pleasure-grounds, and conservatories, are of the very highest curative effect.

The buildings are constructed with taste and with a strict attention to the means of ventilation and comfort. Everything is avoided which can give the idea of a prison or of confinement; while the arrangements are such, at the same time, as to afford security to the inmates. The galleries are cheerful, spacious, and well lighted; and all the rooms and airing-grounds command an agreeable prospect. Workshops are provided for the industrious, and in these the carpenters, tailors, shoemakers, and other tradesmen, pursue with happiness their several occupations. The females are encouraged in habits of industry, and sew, knit, and embroider in their workrooms, or assist in the culinary department or the more laborious duties of the washing-house and laundry. The rooms and workshops are neatly furnished, and the walls are hung with drawings or paintings. Flowers and singing birds everywhere cheer the eye and the ear. Books, and periodicals, and newspapers, are liberally supplied, and perused with avidity. Each day is commenced with careful ablutions, followed by morning prayers. To a comfortable breakfast succeed the various occupations of the day, when each one follows out the occupation prescribed for him, assisted and encouraged by the kind acts of his attendant, and stimulated to exertion by some trifling reward. Dinner is served with all the comfort and regularity of a private meal; and work is again resumed. At an early hour tea is followed by amusement of some kind; in the summer time by cricket, bowls, quoits, or some other open-air game; in the long evenings by a reading party, a lecture, a concert, or dance, some dramatic representation, or some in-door games suited to the taste and capacity of those engaged. Some are encouraged to prosecute a systematic course of reading or the study of some science, while others are induced to undertake some literary labours. All are as far as possible made to feel themselves happy and contented in the prosecution of some purpose, which carries their mind away from the subject of their disease, and which is adapted to their capacities, their natural tastes, or the peculiar phase of their malady.

This institution is, or should be, regulated and directed, throughout all the details of its management and daily routine, by a physician of the highest natural and professional ability. The qualifications for such an office are indeed of the rarest kind; but they are at the same time indispensable. He must unite the natural endowments of benevolence and firmness. He must be good and humane, and at the same time just and inflexible; courageous and calm, tempering firmness with serenity, and kindness with decision and impartiality. He must be possessed of a sound practical knowledge of human nature in all its phases, and that innate power or tact which enables one to govern others with ease, to acquire their confidence and esteem, and at the same time to command their ready obedience and respect. He must be acquainted with the usages of society among all ranks and among all the varieties of human character. He must be versed in polite literature, and must have a taste for the lighter accomplishments of civilized society, so as to be able to direct and give an impulse to the amenities of asylum life. He must have a general knowledge of business, of house architecture and engineering, of farming and gardening, botany and natural history, and of the various trades and manufactures, so as to qualify him for the superintendence of a large institution where operations in all these departments require to be directed and encouraged. Combined with these general qualifications, he must be skilled in his own profession in all its departments, so as to give the advantage of enlightened professional skill to the medical treatment of his patients.

Under the advantages of such an institution as we have described, and under the care of a physician with such qualifications as those enumerated, it cannot be doubted that an asylum affords the best prospect of recovery in curable insanity, and the best means of affording happiness and prolonged life in the incurable forms of this malady. That many of the best asylums of this and other countries possess all these means and appliances, and are conducted with consummate skill and benevolence, is not now a matter of doubt, but one of grateful reflection to every philanthropic mind.

Increase of insanity.

It is a question of great interest, but of no little difficulty, at the present moment, to determine whether insanity is on the increase in this and other civilized states. The statistics of insanity, the gradual increase in the number of public and private asylums, and the rapidity with which they are filled as soon as erected, all seem to indicate a great increase in the numbers affected with mental disease. On the other hand, it is certain that statistical inquiries have in successive periods been conducted with much greater minuteness; that cases are now sent to asylums which formerly were allowed to go at large or were treated at home; that as the advantages of early seclusion in an asylum are becoming more widely known, and the prejudices against those institutions are dying out, friends more readily resort to them for the care or cure of their relatives, even under the slighter forms of insanity; and lastly, the legal enactments for the provision of pauper lunatics have gradually become more stringent, and few cases of idiocy, or epilepsy, or monomania, are now permitted to wander at large. These causes have given an apparent increase to the number of those returned as insane; and it is impossible at present to determine whether there is actually any absolute increase in the ratio of the insane to the sane portion of the population.

Laws regarding insane.

In England and Ireland no one can be sent to an asylum without an order from a relative, and the certificates of two medical men who have separately examined, the patient, and who are required to state the grounds upon which they formed their opinion in their certificate. In the case of paupers the order of a justice of the peace is required. In Scotland the sheriff of the county grants a warrant for the removal of a patient to an asylum upon an application or petition from a relative or guardian, accompanied by the certificate of one or two medical men. If these rules are not attended to, the person sending and the person receiving a patient into an asylum are liable in heavy penalties.

The restriction of one's liberty by his being placed in an asylum is a means of cure or safety, and does not in itself deprive the individual of his legal rights. He can only be deprived of these by a regular form of inquiry, whereby he is declared insane by a commission, or by the verdict of a jury.

The existence of insanity does not in itself disqualify for legal acts, or exonerate from responsibility for acts of violence or murder. Wills have been held to be good although executed by persons who were confessedly insane; but it was considered that their insanity, or the delusions under which they laboured, were not of such a kind as to interfere with their judgment in the disposition of their affairs. In the same manner persons have been held responsible for criminal acts about whose insanity there was no doubt, but it was deemed not to be of such a nature as to prevent them knowing right from wrong in the act which they committed. These subjects involve intricate and difficult medico-legal questions, and can only be briefly indicated here.

IV.—IDIOCY,

Idiocy.

Or Idiotism, is a natural or congenital weakness of the mental powers, and varies in degree from slight impairment or imbecility, by gradual and insensible shades, down to absolute idiocy, or total absence of intelligence.

Idiocy depends upon some congenital disease of the brain, or the want of the due development of that organ

In the former case the head is often large and misshapen, and in the latter it is generally small, and also irregular in shape. The form of the head; the low, retreating, and contracted forehead; the flattening of the occipital region and the expression of the thick-lipped face; the figure, which is generally small and deformed;—are all familiar, and are strongly indicative of the mental condition.

Idiocy exists to a very great extent in certain districts where goitre or bronchocele (an enlargement of a structure in the neck) is found to prevail. These districts are mostly the valleys at the foot of lofty mountains, where the air is stagnant and humid. This disease is called *cretinism.* It prevails to an enormous extent in some portions of Switzerland, Sardinia, and Austria. In the Canton du Valais 1 in every 25 inhabitants is a cretin, in the Canton de Vaud 1 in every 27, and in the Canton d'Uri 1 in every 83; in Judenburg in Austria there is 1 to every 53 of the population, and in Bruck 1 in every 74. In Upper Austria, along the banks of the Danube, whole families consist of cretins; and in some villages of from 4000 to 5000 inhabitants not one was found capable of bearing arms. In many other mountainous districts in Europe and other parts of the globe this endemic disease is found to exist.

The subjects of this affection exhibit idiocy in its most absolute and loathsome form. They are diminutive creatures with large bellies and misshapen limbs, heads of unusual form or size, blear and sunken eyes, flat noses, and large lips, the tongue protruding, the mouth open, and the saliva running from it. The skin is loose and yellow. The poor victims of this disease can neither see, hear, nor speak; they can scarcely creep from place to place, and are lost to all sense or intelligence beyond the bare instincts of animal life. This description refers to the worst class of cases. Many of them display a certain degree of intelligence; but although treated with extreme kindness, they are obstinate, mutinous, and incapable of gratitude. They seldom live beyond thirty years of age.

The causes of this disease have been sought for in the water which is drunk by the inhabitants of the affected districts, in the confined and humid atmosphere which they breathe, and in their filthy and crowded houses, their intermarriages, and their intemperate and lazy habits.

By Dr Guggenbühl and some other authorities this condition is considered to result from a disease analogous to rickets, and affecting also the cerebro-spinal system, and that by appropriate treatment adopted at an early age it may be cured. His treatment, combined with a gymnastic and educational training, has been successfully pursued for some years in his establishment at Interlachen.

We have already briefly alluded to the various institutions in this and other countries which have been recently organized for the care and improvement of idiots. It remains yet to be seen how far the mental faculties and moral emotions of this class of unfortunates can be developed and elevated by proper training and treatment; but the success which has already attended the philanthropic labours of those who have entered upon this path of benevolence is of the most gratifying and encouraging description.

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MENTSCHIKOFF, or Menzikoff, Alexander, an eminent Russian general and statesman, was the son of a peasant, and was born near Moscow in 1674. While plying his trade as a pastry-cook's boy in the streets of the capital, he attracted the notice of Lefort, the favourite of Peter the Great. Having become the servant of that nobleman, he showed so much talent that his master raised him from the office of a menial, and instructed him in the affairs of war and government. On the death of Lefort in 1699 Mentschikoff succeeded to his place in the favour of the czar. Nor was he an unworthy successor. He distinguished himself at the siege of Schlüsselburg in 1702; and in 1704, so notable had been his services that he was appointed governor of Ingria, and was honoured with the rank of a prince and with the title of major-general. In the war against Charles XII. of Sweden Mentschikoff bore an important part. In 1706 he routed the Swedes in a pitched battle; in 1709 he led on the left wing at Pultowa, and in the flight that followed that decisive victory he compelled Lewenhaupt, the Swedish general, to capitulate. Hitherto his style of living had been simple and unostentatious. But no sooner had Peter the Great in 1711 set out on his expedition against the Turks, and left him in charge of the government at St Petersburg, than he erected a palace, increased the number of his servants, and began to give the most sumptuous banquets. At the same time, his riches swelled to such a suspicious extent, that on the czar's return he would have been punished for embezzlement of the public money had not his former distinguished services palliated the offence. Restored to favour, Mentschikoff was appointed commander of the army in the Ukraine in 1719, and ambassador to Poland in 1722. About this time he was anxiously looking for the death of the czar, and was employing all his penetration to discover the likely successor to the crown. On attaining the object of his scrutiny he timed his conduct so ably, that on the death of Peter in 1725 he was raised to the summit of power under Catherine I. Two years afterwards that princess died, charging her heir, Peter II., to espouse the daughter of Mentschikoff. But the eagerness of the ambitious father to bring about the espousals disgusted the young prince; the suggestions of the Dolgoroukis, the royal favourites, intensified that disgust; and in a few days Mentschikoff was sentenced to be banished to one of his own estates. Obeying the sentence with a defiant haughtiness, he left the city sitting in his handsome chariot, wearing all his badges, and attended by troops of servants. Before he had proceeded far, however, he was overtaken by the emissaries of the czar, stripped of all his pomp and magnificence, clothed in the garb of a peasant, and conducted in a covered waggon, along with his family, into Siberia. His wife had died by the way; his eldest daughter fell a prey to the small-pox soon afterwards; but Mentschikoff himself, while shivering in a rude hut, and digging an inhospitable soil for bread, maintained his spirit unbroken. He began to seek the consolations of religion, and died of apoplexy on the 2d November 1729 while engaged in erecting a wooden chapel. He was the first count and the first prince created by a Russian sovereign, and was the founder of a family which cannot boast of any very distinguished name till we come to his grandson, the present Prince Mentschikoff, the celebrated general who defended Sebastopol.

MENTZ. See Mayence.

MENZELEH. See Egypt.

MEPPEL, a town of Holland, province of Drenthe, on the Reest, near its confluence with the Echtinger and Havelter, 26 miles S.W. of Assen and 6 from the Zuider Zee. The town has two churches, a synagogue, schools, &c.; and establishments for the manufacture of linen and cotton stuffs, canvas, leather, hats, and tobacco; besides breweries, boat-building yards, bleachworks, &c. Pop. 6070.

MEQUINEZ, a town of Morocco, province of Fez, in a fertile valley, 70 miles E. of Sallee and 34 W. S. W. of Fez. The houses, which are generally only one storey high, are neat and well built; but the streets are unpaved. The town is surrounded by a wall 6 feet high, which serves as a defence against the attacks of the Berbers. The principal building is the palace erected by Sultan Muley Ismael, who made Mequinez one of the capitals of his dominions; and it is still occasionally the residence of the sultan. The palace is extensive, but low, and contains fine gardens and marble-paved court-yards. It is built of marble, and adorned with fountains of the same material; while the walls are inlaid with red and blue tiles. The manufacture of leather is carried on in the town; and in the vicinity there are large plantations of olives. Pop. about 70,000.

MERCARA, a town and fortress in the south of India, is situated within the British district of Coorg, of which it is the capital. It was built by Hyder Ally in the year 1773, after he had conquered the country. Upon the conclusion of peace with Tippoo Sultan in 1792 it was given up to the rajah of Coorg; but upon the contumacious conduct of this prince in 1834, it was occupied by a British force under Colonel Lindsay, and the rajah being soon after deposed, the present British establishments were formed. It is 72 miles E. from Seringapatam. Long. 75. 48. E., Lat. 12. 24. N.

MERCATOR, Gerard (the Latin name generally given to Gerhard Kauffmann), one of the most celebrated geographers of his time, was born at Rupelmonde in Flanders on the 5th of March 1512. After completing his elementary studies at Bois-le-Duc, he went through a course of philosophy at the university of Louvain, where he took his degree. Having applied himself with extraordinary ardour to the study of geography and mathematics, he soon received the patronage of the Emperor Charles V., and in 1599 was nominated cosmographer to the Duc de Juliers at Doesburg, where he died in 1594, at the advanced age of eighty-three years. He is principally known from having given his name to the projection generally employed in nautical maps, in which the meridians and parallels are represented by straight lines which mutually intersect at right angles. Besides executing tables of chronology and geography, he published many valuable maps, engraved and coloured by his own hand.

His works are,—*Chronologia a Mundi exordio ad ann.* 1568, Köln., fol., 1569; *Tabulæ Geographicæ ad mentem Ptolemæi restitutæ*, fol., 1578; *Globi Terrestris Sculptura*, 1541; *Globi Cœlestis Sculptura*, 1551; Atlases, 1595, 1628, 1633. He also published two theological works,—*Harmonia Evangelistarum*, 1592; and *De Creatione ac Fabrica Mundi;* the latter forming a dissertation prefixed to his Atlas of 1595, and which was condemned by the church for setting forth certain heterodox views respecting the doctrine of original sin.

Mercator, *Nicolas* (the Latin name of Nicolas Kauffmann), an eminent mathematician, was born at Holstein in Denmark in 1640. He visited England in 1660, when he was chosen a member of the Royal Society, and returned to Paris previous to his death in 1687. He was the first to detect the defect of Gerhard Mercator's projections, afterwards rectified by Edward Wright. Of all his works on cosmography and mathematics, by far the most original and valuable is his *Logarithmotechnia, sive Methodus Construendi Logarithmos Nova; cui accedit Vera Quadratura Hyperbolæ, et Inventio Summæ Logarithmorum*, London, 1668–1674, 4to.

MERCIA, one of the ancient kingdoms of the Saxon heptarchy in England, bounded on the N. by Northumbria,

E. by East Anglia and Essex, S. by Wessex, and W. by Wales; and including the modern counties of Chester, Derby, Nottingham, Lincoln, Salop, Stafford, Leicester, Rutland, Northampton, Huntingdon, Hereford, Worcester, Warwick, Gloucester, Oxford, and Buckingham, along with parts of Hertford and Bedford. It is believed to have been founded by a body of Angles under Crida in 585 A.D. It was conquered by the Northumbrians in the seventh century, but soon after regained its independence, subdued the kingdoms of East Anglia and Kent, and was finally incorporated in his dominions by Egbert, King of Wessex, in the year 825.

MERCIER, Louis Sebastien, an eccentric French writer, was born in Paris in June 1740. After publishing several heroic epistles, and holding for some time the professorship of rhetoric at Bordeaux, he first displayed his satirical power in *L'An* 2440; *Rêve, s'il en fut jamais*, Amsterdam, 1771. In his *Essai sur l'Art Dramatique* he struck at the fame of Corneille, Racine, and Voltaire, and proposed, with grave self-conceit, to replace their dramas by his own productions. The comedians, however, rejected this proposal, and brought down upon themselves the satirical lash of Mercier. A more legitimate subject of satire was the corrupt social system of the French capital. Accordingly, in 1781 Mercier began to attack it in the first two volumes of his famous *Tableau de Paris*. While this work was exciting a great ferment in the nation, the vanity of the author would not suffer him to remain anonymous and to see it attributed to others. He therefore discovered himself to the inquisitor Lenoir, but thought it advisable at the same time to betake himself immediately to Neuchatel, and to publish the remaining ten volumes there. After visiting Germany, Mercier returned to France on the eve of that revolution which he vauntingly attributed to his *Tableau*. He assisted Carra for some time in editing *Les Annales Patriotiques* and *Chronique du Mois*. As a member of the Convention for the department of Seine-et-Oise, he voted for the perpetual detention of the king. Having been admitted in 1795 into the Council of the Five Hundred, he opposed the motion that Descartes should receive the honours of the Pantheon. He also signalized himself by his vehement invectives against education, which he styled "the pest of the human race." On his retirement from this council he was appointed professor of history in the central school, and a member of the newly-formed institute. Mercier died at Paris in April 1814. Among his numerous works are,—*Mon Bonnet du Nuit*, in 4 vols. 8vo, Neuchatel, 1783; *Histoire de France depuis Clovis jusqu'au Règne de Louis XVI.*, in 6 vols. 8vo, 1802; and *Neologie*, in 2 vols. 8vo, Paris, 1801.

MERCURIUS, a Roman divinity. The connection of his name with *merx*, goods, and *mercari*, to traffic, indicates that the first idea of his character was that of the patron of merchandise. As the Latin writers, however, became intimate with the literature of Greece, they identified his life and functions with those of the Greek god Hermes. Mercury, therefore, was said to be the son of Jupiter and Maia, and to have been born in a cave of the Arcadian mountain Cyllene. Scarcely had he seen the light when he seized upon a tortoise, and out of its shell framed the first lyre. He then proceeded to Pieiria, and drove off part of the flock of Apollo to a cave in Pylos. The owner detecting the theft, pursued, and recovered his property; but was so charmed with the music of the newly-invented lyre, that he returned the oxen, and presented to the young god a golden staff called *caduceus*. At the same time Jupiter installed him in the office of herald and messenger of the gods. In this capacity Mercury tied Ixion on the wheel, chained Prometheus to Mount Caucasus, assisted Perseus to kill Medusa, conducted Juno, Minerva, and Venus to Paris, and slew Argos the hundred-eyed. He was also employed to lead the ghosts of the dead to the other world, to infuse dreams into the brain, and to cause or dispel slumber by the passes of his magic wand. From his character as a herald, Mercury came to be considered an adept in eloquence, and therefore the patron of orators, poets, and other men of genius. Since his office also led him to be the promoter of intercourse and agreement between parties at a distance from each other, he was regarded as the god of commerce and of all the other means that produce peace and unity among nations. Yet as he was sometimes sent on hostile missions, and was not scrupulous on these occasions about the devices he employed, he was supposed to listen to the prayers of thieves and robbers. His patronage was likewise extended to shepherds, musicians, travellers, and athletes. He is said to have invented letters, arithmetic, astronomy, music, and the syrinx. The two most celebrated temples of Mercury were situated, the one upon Mount Cyllene in Arcadia, and the other near the Circus Maximus in Rome. His festivals were called *hermæa*. His images, styled *hermæ*, were set up at cross roads and in the porches of temples and mansions. Mercury is generally represented as a naked youth, displaying in his limbs the beauty of the boy mingled with the full vigour of manhood, holding a purse in his right hand and his winged *caduceus* in his left, wearing one pair of wings on his sandals and another on his hat, and bending forward on tiptoe, as if speeding over sea and land on some important errand.

MERGUI, a town of Hindustan, and the capital of the British district of the same name, in the Tenasserim provinces, is situated on the principal mouth of the Tenasserim River. It is about three miles in circuit: the streets are wide; and the houses, which are built chiefly of wood, are raised on piles from the ground. The harbour is spacious, secure, and easy of access for ships of any size. Pop. about 12,000. The place was taken by the British during the first war with the Burmese, and confirmed to the conquerors, with other territory, by the treaty of Yarid-Abhoo concluded in February 1826. Lat. 12. 27., Long. 98. 42. Opposite to the coast is a cluster of islands denominated the Mergui Archipelago, the principal of which are,—the Great and Little Canister, King's Island, Cabossa, Bentinck, Domel, Kisseraing, Sullivan's, and St Matthew's.

MERIAN, Jean Bernard, an eminent philosopher, was born at Leichstall, in the canton of Bâle, in 1723. His father, who was a highly respected pastor in his native town, removed to Bâle, and was placed in 1738 at the head of the Protestant churches of the canton. The objects of study which attracted him most were poetry and philosophy; for he possessed in an almost equal degree a taste for philology and philosophy, for metaphysics and the fine arts. Having received his doctor's degree at the age of seventeen, he soon after entered the church, and distinguished himself as a preacher. After a short residence at Lausanne, which enabled him to perfect himself in the French language, Merian accepted the place of preceptor to the sons of a gentleman in Amsterdam, where he spent four years. In 1748 he received from Maupertuis, president of the Academy of Berlin, an invitation to attach himself to that learned body, with the offer of a pension from Frederick II. Merian did not hesitate to respond to this flattering proposal, but came immediately to Berlin, where, during more than half a century, he exerted a most salutary influence not only over the Academy of Sciences, but over public instruction in general in Prussia. He enriched the philosophical literature of the academy by a series of memoirs on some of the most important problems in morals and metaphysics, and which are generally regarded as masterpieces of clearness and impartiality. On the death of Formey, whose *éloge* he pronounced in 1797, Merian was appointed perpetual secretary to the academy. He died on the 12th of February 1807, lamented by many of the greatest names in Europe, with whom he had been long associated, such as Euler, Lagrange, Sulzer, Lambert, Ancillon, &c.

At the request of Frederick II. Merian translated Claudian's *Enlèvement de Proserpine;* and afterwards published the *Essais Philosophiques* of David Hume, and the *Lettres Cosmologiques* of Lambert. In his philosophical memoirs his main object is to combat the philosophy of Leibnitz. These will be found in the Memoirs of the Academy of Berlin, extending over a period of upwards of forty years, from 1749 to 1804. (For farther information respecting Merian, see the *Eloge Historique* of Fr. Ancillon, published in the Memoirs of the Berlin Academy for 1810; also *Cours d'Histoire de la Philosophie Modern* of Victor Cousin, vol. i., first series; and the *Dictionnaire des Sciences Philosophiques*, Paris, 1849.)

Merian, *Matthew*, an eminent painter, was the son of a distinguished engraver of the same name, and was born at Bâle in 1621. After studying under his father and Sandrart, he travelled to complete his education in his art, and became intimate with Vandyck and Rubens in England, with Vouet and Lesueur in France, with Sacchi and Maratti in Italy, and with Jordaens in the Netherlands. He settled first at Nuremberg, and afterwards at Frankfort-on-the-Main. In the latter city he painted, after the style of his master Vandyck, the portraits of the Emperor Leopold I. and several other German princes. These works were rewarded with both money and honours. Yet at the same time Merian conducted the trade in books and prints which his father had left him. He died at Frankfort in 1687.

Merian, *Maria Sibylla*, a skilful drawer of insects and other subjects of natural history, was the sister of the preceding, and was born at Frankfort-on-the-Main in 1647. She was instructed in drawing by Morell, her step-father, and Abraham Mignon, and soon displayed a notable taste and truthfulness in her sketches of flowers, butterflies, and caterpillars. In 1665 she was married to John Andrier Graff, a painter of Nuremberg, but was still known by her maiden name. Her studies and her scientific excursions were not interrupted, and the first result of her labours was published in 1679–83, under the title of *The Origin of Caterpillars, their Nourishment and Changes,* in 2 vols. 4to, Nuremberg. A Latin translation of this work appeared in Amsterdam in 1717. In 1684 she and her husband were induced by offers of patronage to settle in Holland. Maria Sibylla's enthusiasm for her art increased with her years. In 1699 she crossed the Atlantic with no attendant but her daughter, and spent two years at Surinam in sketching the insects, shells, and plants of the new world. A part of these sketches was published in her *Dissertatio de Generatione et Metamorphosibus Insectorum Surinamensium,* Amsterdam, 1705. Maria Sybilla Merian died in 1717. A new edition of her last work was published soon after her death, with twelve plates by her two daughters. Her former work, enlarged by herself and her daughters, was published in French by John Marret, under the title of *Histoire Générale des Insectes de l'Europe*, folio, Amsterdam, 1730. These two corrected works were published together under the common title of *Histoire des Insectes de l'Europe et de l'Amerique*, folio, Paris, 1768–71.

MERIDA (*Augusta Emerita*), a town of Spain, in the province of Estremadura, and about 35 miles from the city of Badajoz, is situated on a small eminence on the right of the Guadiana. It is tolerably well built; contains two parish churches, two hospitals, four schools of primary instruction, three ex-convents, and two nunneries. Of the two churches, that of Sta. Maria is a clumsy quasi-Gothic edifice, partly built of the innumerable Roman remains; that of Sta. Olalla (*Eulalia*) is said to date from the fourth century, and is dedicated to one of the earliest martyrs of Spain. Her name is also borne by a convent on the Madrid road, and by a statue and chapel in the space called Campo de San Juan; the latter, called El Hornito (*Oven*) de Sta. Olalla, now in ruins. Merida is remarkable for its Roman remains, in the number and magnitude of which it may be almost said to vie with Rome itself. The Guadiana is crossed by a bridge 2575 feet long, and consisting of 81 arches wholly of granite, erected by Trajan. Some of the arches were destroyed in 1812 to impede the advance of Marmont upon Badajoz. Of the colossal wall that formerly surrounded the town, there only remains the part defending the Roman castle called El Conventual. In the town are still some relics of the temples of Mars, Diana, Fortune, and others, and of a triumphal arch (*De Santiago*) 44 feet high, built by Trajan, and now stripped of its marble casing. Of an ancient aqueduct from Lake Albuera thirty-seven enormous pillars are still standing, and ten arches, in three tiers, built of brick and granite. To the east, and crossing the Madrid road, are three pillars of another aqueduct, the materials of which were employed in the construction of that which at present supplies the town with water. Farther east is the circus, 1356 feet by 335, well preserved, and capable of containing on its eighteen tiers of seats the whole present population of Estremadura. East of the circus is the amphitheatre, called the Siete Sillas, from its seven rows of seats, still almost entire, as are the vomitories. Before the French invasion it was used as a Plaza de Toros. Near it is the Naumachia, vulgarly called the Roman Baths, of which the oval form, 400 feet in length, is barely traceable. Augusta Emerita was built in 25 B.C. by the emeriti of the fifth and tenth legions, who had served in the Cantabrian war under Augustus. It rose to great splendour and importance as the capital of the province of Lusitania, was taken by Musa in 715, and reconquered by Alonzo in 1228.

The population is mostly agricultural; the surrounding country producing wheat, oats, legumes, oil, and wine. Large herds of swine are reared, with sheep, goats, and horses. There are manufactures of white soap in the town. Pop. 3780.

Merida, a town of Venezuela, capital of a province of the same name, is situated on a plain 5518 feet above the level of the sea. The town is well and regularly built, with straight streets crossing each other at right angles, and having a clear stream of running water in the centre of each. It was formerly one of the largest towns of Venezuela, but having repeatedly suffered from earthquakes, especially in 1812, it has greatly declined. The town has a cathedral, nunnery, a college, several schools, and an hospital. Woollen and cotton stuffs are manufactured; and the surrounding country produces coffee of great excellence. The province occupies an area of 10,793 square miles. Pop. of the province (1854), 23,967; of the town, 6800.

Merida, a town of Mexico, capital of the state of Yucatan, is situated in a dry plain, 25 miles from the sea, and 90 N.E. of Campeachy. Lat. 20. 50. N., Long. 89. 40. W. The town, which was founded by the Spaniards in 1542 on the site of an earlier native city, is built in the Moorish style. There are eight principal streets, wide and sloping towards the centre; and these are laid out with great regularity, meeting in a large square in the centre of the town, in which stand the cathedral, the bishop's palace, and the government house. The cathedral is ancient, and has a fine appearance, being adorned with domes and pinnacles. The town has also fourteen churches, and the ruins of an old Franciscan convent, which are curious and interesting. The climate is dry and not liable to sudden changes, but it is not very healthy. Merida has a considerable trade. Its port is Sizal, which is but an exposed roadstead with a fort and a sandbank 12 miles in length. Pop. (1851) 40,000.

MERIONETHSHIRE, the most southern county of North Wales, is situated at the middle of the Welsh coast, and is of a triangular form, the apex terminating between Corwen and Llangollen; the base being formed by Cardigan Bay, with a portion of Carnarvonshire; the perpendicular by Carnarvonshire and Denbighshire; and the hypothenuse by Denbighshire, Montgomeryshire, and Cardiganshire. The length from north to south is 56 miles, and its greatest breadth 32 miles. Its area is estimated at 602 square miles, or 385,291 statute acres.

The coast is iron-bound and dangerous, from shoals and banks, as Sarn-Badrig, Sarn-y-Bwch, Dutchman's Bank, &c. At Aberdovwy, however, there is a safe harbour, which might be rendered more so by a little enterprise. Abermaw is another safe creek, though not so safe as Aberdovwy. In fine weather large boats can land in Aberdiswnwy, Moehras, and Traethbach.

This county, in its physical aspect, is one of the most interesting in the principality; and while inferior to some others in stupendous boldness, it equals any in calm sublimity, and is superior to all in richness, variety, and beauty. Its mountains, though not very lofty, greatly excel in colouring and outline; whilst the greater prevalence of trees, blending harmoniously with fantastic crags, dark deep dells, frowning mountains, smiling vales, a sea-board deeply indented with lake-like estuaries, completes such a scene as can never fail to entrance an eye in sympathy with nature.

The Merionethshire mountains may be ranged in five groups, named after the principal eminence in each:—1st. Moelwyn group (2566 feet), being a spur of Snowdon. 2d. Arenig group (2809 feet), extending from Festiniog to Bala. 3d. Rhiniog Vawr range (2863 feet), sometimes called Harlech group. 4th. Aran Mawddwy range (2955 feet), extending from Aberdovwy to Corwen. 5th. Cader-Idris group (2914 feet), being a spur of the Aran Mawddwy range, having Craig-yr-Aderyn (*i.e.*, Bird's Rock), one of the most remarkable rocks in the kingdom, appended thereto.

The Dofwy, the Diswnwy, the Talyllyn, the Mawddach, Festiniog, and the Madawc vales are the most remarkable, and add exceedingly to the exquisite effectiveness of the scenery, permitting a fuller view of the mountains from base to summit than is usually the case in other counties.

The chief rivers are the Dwfrdwy (Dee), which, emerging from Bala Lake, enters Denbighshire near Corwen, then passing through a slip of Cheshire and Flintshire, expands into a vast estuary of the Irish Sea, separating the two counties. The Dofwy, originating in a small lake under Aran Mawddwy, expands into an estuary of Cardigan Bay at Aberdovwy, and is navigable for 8 miles. The Diswnwy, emerging from Llynmwyngil, expands into a small shallow estuary, which contracts into a narrow, tortuous channel as it enters the sea near Sarn-y-Bwch. It is only navigable for boats for 3 or 4 miles.

The Mawddach, issuing from the skirts of Aran Mawddwy, and forming a junction with Llynau-duon and the Wnion, expands into a considerable estuary of Cardigan Bay at Abermaw, and is navigable for 8 miles. The Cynval and others, uniting their streams, form a considerable estuary, called Traethbach, at the bottom of the vale of Festiniog, and is navigable for boats only, being fordable at low water. Glaslyn and Dwyryd (or the Eryri) uniting, enter the bay at Porthmadawc, where the estuary has been embanked, and a vast district recovered, through the enterprise of the late Mr Madox.

The lakes are small, but numerous, amounting to sixty-four or more. The largest are Llyn Tegid (*i.e.*, Fairy Lake), sometimes called Pimble-mere, near Bala, being 4 miles long and 1 broad, its banks being most picturesque; and Llynmwyngil (*i.e.*, the Lake in a Sweet Nook), in the well-known vale of Talyllyn, which, though only a mile long, is perhaps more interesting still, and well deserves its Cambrian name. It is much frequented by anglers, who find ample sport, though the trout is not over delicate. The other lakelets are generally very interesting, both in regard to scenic effect and sport. One of them, Llynewmbychan, has a snow-white deposit of kaolin or porcelain clay.

A good many fine waterfalls exist, which add greatly to the romantic beauty of the prospect. The most considerable are Rhaiadr-y-Glyn, near Corwen, and Rhaiadr Mawddach and Pistill Caen, near Dolgelley; the latter being 150 feet high.

The prevailing geological formations are felspathic trap, porphyry, and other unstratified rocks; whilst the secondary hills are composed of different kinds of schist, interspersed with unstratified elvan. Along the Dee a bluish-gray limestone is found, and white limestone at Corwen. This formation is surrounded by primitive argillaceous slate.

Gold, silver, copper, and lead mines abound, but as yet they have not proved profitable speculations. The extravagant royalty which is demanded by proprietors is a serious bar to mining adventure here. Llyn-y-Pair mine, near Aberdovwy, is now very promising, and the mining interest consequently beginning to look upon the county with greater favour. There are extensive deposits of iron, manganese, and other minerals, but royalty and transit expense render their working unprofitable.

The slate quarries of Festiniog and Corris are extensive and most remunerative speculations. In the former at least 3000 persons find constant employment; Mrs Oakley, Lord Palmerston, and Messrs Greaves and Holland being the principal proprietors. The most extensive quarry at Corris is that of Aberllefeni, the property of R. D. Jones, Esq. This slate is of a deep blue, of considerable tenacity and hardness, but yet easily worked. It is preferred for roofing important buildings and the manufacture of articles enamelled by Magnus's beautiful process.

The variety of altitude and aspect incident to a mountainous yet maritime country results in producing a variety in the climate; Aberdovwy, for instance, being proverbially mild, the myrtle standing the winter as well as any common shrub; whilst neighbouring places differently situated are bleak and cold.

More than half the county is uninclosed, and much even of that is unproductive. Considerable portions of marsh land have been reclaimed in the estuaries, and much more requires only capital and enterprise in order to bring it to as fertile a condition as any in the county. The proportion of arable land being small, it is consequently high-rented. The best is found about Towyn and Dyffryn-Ardwydwy.

The farming is generally of an inferior kind, and the farm buildings and cottages worse still; whilst rents, wages, and taxes are high. Being essentially a pastoral county, extensive herds of sheep are kept, which are small in size, but their flesh is delicate, and their wool of very fine quality. Large droves of black cattle of a very superior kind are also bred and annually sold in England, where good feeding converts them into the most tender of beef.

Manufactures are few, except that of flannel, which is produced in large quantities and of very fine quality. The women in some localities are still noted for knitting stockings, gloves, and Welsh wigs, which are exported, but to a much more limited extent than formerly, when it amounted to some L.25,000 per annum. That of slates should be included amongst manufactures, as distinct from quarrying, and this would increase the importance of the manufacturing interest of Merionethshire considerably. Brush-handles, clogs, gloves, and leather for the same, are also manufactured to a limited extent.

The chief commercial outlets are Aberdovwy and Abermaw. The trade of the former place is extensive and increasing. The exportation consists mostly of slates, poles, bark, and ores The importations are,—shop goods, corn, limestone, culm, coal, timber, &c. The trade of Barmouth has rather declined of late years. There is a harbour trust there who have managed to squander much money to very little purpose in attempting to build a lighthouse.

Aberdovwy, Towyn, and Abermaw or Barmouth are much frequented in the bathing season. Towyn frequently has its population trebled in a week by the influx of the industrial classes on their annual pilgrimage to the sea-coast; a privilege for which express stipulations are made in hiring engagements in Montgomeryshire, from whence most of them come.

There are two royal ferries; and their management does not reflect much credit upon the Board of Works, by whom they are leased to parties who do not appear to be particularly studious of the convenience and interest of the public. The want of railroads is much felt by strangers; but it is hoped that the proposed new railroad to Machynlleth will soon go far to remedy this serious hinderance to the material progress of the county. Dolgelley and Bala, where the assizes are alternately held, are two interesting little county towns of a purely Welsh character. The former has been lately lighted with gas; but both are very defective in sanitary arrangements. Corwen is a delightful and progressive place, from its proximity to a railway; Aberdovwy is also an improving locality, and must become a most important seaport, from its fine harbour, when the Machynlleth Railway is finished. Abermaw is a romantic watering-place much frequented. Of Harlech and Dinas-Mawddwy very little remains, save a fine old castle in the one, and a sinecure corporation in the other. Festiniog is a populous slate-manufacturing town surrounded with beautiful scenery. The following is the population of the principal towns:—

Names of Towns.	1841.	1851.	Males.
Aberdovwy and Towyn	2907	2769	1322
Dolgellau	3695	3479	1578
Bala and Llanycil	2461	2431	1198
Festiniog	3138	3460	1878
Abermaw and Llanaber	1709	1672	725
Corwen	2129	2069	1029

The Anglican Episcopal community is the church established by law, but it has few adherents and little influence among the people. The county is ecclesiastically divided between Bangor and St Asaph. The deaneries of Ardwydwy, Estimaner, and Talybont, are in the former; and Mawddwy, Penllyn, and Edeyrnion, in the latter. The number of parishes is about thirty-four, and, for a poor country, they are well endowed.

The dominant non-established church is Presbyterian, in the form called Welsh Calvinistic Methodism. The Wesleyans, Congregationalists, and Baptists have also numerous congregations.

Education is carried on by means of some hundreds of Sunday schools, and sixty day schools. There are two colleges at Bala for the education of Methodist and Congregational ministers: the former is being endowed as a fitting monument to the great and good Thomas Charles, who was to Welsh Methodism what Wesley was to Wesleyanism, and who lived and laboured in this town for many years.

In the earliest historical period Merionethshire was included in the territory of the Ordovices, a tribe so called through a Roman corruption of their Celtic designation, *Ardovwysiaid*, or "dwellers upon the placid stream." During the Roman occupation it was included in the province of *Britannia Secunda*, being (some say) called *Mervinia*; if so, it would seem to indicate an earlier origin for the word Merioneth (or Merion's Land) than the fifth century, when the Cantrev, or district situated between the Dofwy and the Mawddach, was bestowed upon Meirion-ab-Tybiawn-ab-Cynedda for his services in expelling the Gwyddelians (Irish) from Gwynedd. Perhaps *he* may have taken his name from the district allotted to him, as it is still as often called Meirion as Merionydd. The *Via Occidentalis* passed the whole length of the county, being joined at *Heriri Mons* (the Mountain of Eryri, now Tomen-y-Mur, near Trawsfynydd) by a branch of the Southern Watling Street. During the Saxon and early Norman period we have not much interesting information respecting it, as it seems to have been to the Kymro a safe and mysterious refuge, into which the Saxon had a wholesome hesitation in following. But in proportion as the Anglo-Norman power became consolidated these impregnable fastnesses became the scene of strife. Here Owen Gwynedd defeated Henry II., and brave Glyndwr rose in arms at the call of friendship and patriotism to resist the usurper of the throne of gentle Henry, and the enslaver of his loved Wales. Tradition and records tell of bloody deeds done here in those and later days by freebooters daring and cruel; the Gwylliaid-cochion, the Gwylliaid-duon, and Ievan ap Robin Herwr, the sea-rover of Aberdovwy, and his *trefrydd* or "bloody home," &c. The whole county is rich in Celtic, Roman, and mediæval remains. The castles of Harlech and Bere, the Cadvan, Porus, and Calexus (a Manx king probably) inscribed stones, the Llanegryn rood screen (restored by W. W. E. Wynne, Esq., M.P.), cromlechau, circles, mounds, cairns, camps, &c., invite the notice of the antiquary.

Only one county and no borough member is returned. Real property was returned in 1815 as L.111,436; in 1850 as L.168,236; showing an increase of L.56,800. We extract the following table of the population from the census of Great Britain in 1851:—

1801	29,506
1811	30,854
1821	34,382
1831	35,315
1841	39,332
1851	38,843

In 1851 there were in the county 8159 houses inhabited, 372 uninhabited, and 31 in process of erection.

MERLIN, or MERDHIN, the name of two ancient British wizards:—

Ambrose Merlin was the reputed son of a demon and of the daughter of a British prince, Demetius, and flourished about the end of the fifth century. He was brought up at a city called Caer-Merlin (the City of Merlin), and supposed to be the present Caermarthen. When a mere boy he recommended himself by his supernatural powers to the notice of King Vortigern. He was afterwards the inseparable counsellor of that monarch, and of his immediate successors Ambrosius, Uterpendragon, and Arthur. His alleged miraculous insight is supposed by Leland to have been merely a knowledge of mathematics far transcending the comprehension of his contemporaries. Allusion is made to Merlin in the *Faëry Queen* and in other old poems. A book of Prophecies attributed to him was printed in French in 1498, in English in 1529, and in Latin in 1554. *The Life of Merlin Ambrosius, his Prophecies and Predictions Interpreted, and their Truth made good by our English Annals*, by T. Heywood, was published in 1641, and reprinted in 1813.

Merlin the Wild, *Merlinus Caledonius*, or *Merlinus Sylvestris*, was a native of Caledonia, and lived in the sixth century. From the *Scotichronicon* of Fordun we learn, that in penance for the death of his nephew, he fled into the woods of Tweeddale, and there lived like a squalid savage for the rest of his days. The same authority also states, that being pursued into his fastnesses by a band of rustics, he sprang from a rock into the Tweed, was impaled on a stake fixed in the bed of the river, and thus, in accordance with his own prediction, died by means of earth, wood, and water. But Geoffrey of Monmouth, in his metrical history of Merlin, ascribes this fate to a page whose death Merlin had prophesied in the terms mentioned above. The grave of Merlin is still shown beneath an aged thorn at Drummelzier, a village on the Tweed. The book of prophecies which has been generally ascribed to Ambrose Merlin is sometimes attributed to Merlin the Caledonian, and was published at Edinburgh in 1615 under the name of the latter. (See part ii. of "Thomas the Rhymer" in Sir W. Scott's *Minstrelsy of the Scottish Border.*)

MEROË, an island, or rather peninsula, of Nubia, formed by the Nile and its tributaries the Atbara and Bahr-el-Azrek, and having the mountains of Abyssinia on the E. and the desert of Bahiouda on the W. It is about 400 miles in length from N.W. to S.E. by 200 in breadth, and consists of extensive plains. In ancient times Meroë was very productive and well cultivated; and although the soil is still good, the country is now for the most part covered with trees and herbage, or barren and desert, while very little cultivation is carried on. The ancient inhabitants of this district had attained to so great a degree of civilization and commercial prosperity that it has been by some supposed that the arts of cultivated life were transmitted from this country to Egypt. This, however, is not very likely, and the most probable conjecture that can be formed seems to be, that in the seventh century B.C. the military caste of Egypt, having left their country on account of some injustice received from the king, settled in Meroë, reduced to subjection the natives of that region, and established there a system of government somewhat similar to that of Egypt, but differing from it in the restraints put upon the power of the kings, and the greater influence of the priestly caste. The ruins of Meroë, the capital, are situated on the right bank of the Nile, 26 miles N.E. of Shendy, and they consist of pyramids and temples for the most part in a state of great dilapidation. The pyramids are in number about 80; and they vary in size from 12 to 60 feet square at the base. The largest is about 160 feet high. They are not of great antiquity, and bear traces of a declining period of art, compared with that of the Egyptian monuments. At various other places in the island of Meroë similar remains and brick mounds have been discovered, from which it would appear that in ancient times this district had been thickly studded with towns and villages.

MERRICK, JAMES, a learned divine and poet, the son of a doctor of medicine, was born in 1720, and attended the school at Reading. Enrolled in 1736 as a student of Trinity College, Oxford, he became tutor to Francis North, afterwards the celebrated First Lord of the Treasury. Merrick's classical scholarship was shown by his edition of the Greek text of Tryphiodorus in 1741, and led to his election as probationer fellow in 1744. He entered into orders, but was prevented by his delicate health from undertaking the duties of a pastorate. After a life spent in congenial study he died in 1769. Merrick was characterized by Bishop Louth as "one of the best of men, and most eminent of scholars." His most important works are,—*Prayers for a Time of Earthquakes and Floods*, London, 1756; *A Dissertation on Proverbs, Chapter* ix., 4to, Oxford, 1744; *The Psalms Translated or Paraphrased in English Verse*, second edition, 12mo, Reading, 1766; and *Annotations on the Psalms*, 4to, Reading, 1768. Of his small poems inserted in Dodsley's collection, the fable of "The Chameleon" is the best known.

MERRY, ROBERT, an English dramatic writer, was the son of a merchant, and was born in London in 1755. After receiving his education at Harrow and at Christ's College, Cambridge, he entered Lincoln's Inn, but was never called to the bar. After his father's death he purchased a commission in the Horse Guards, where he held the post for some years of lieutenant to the first troop under Lord Lothian. Anxious for a change, and desirous of seeing the world, he quitted the service, and visited France, Switzerland, Italy, Germany, and Holland. He spent a considerable time in Florence; and during his residence there had the honour of being made a member of the celebrated Della Cruscan Academy. He became a chief contributor to the *Florence Miscellany*, a periodical produced by the joint efforts of a few English residents. In return for the honours done him by the Della Cruscans, Merry attached the name of the academy afterwards as a signature to many of his poetical effusions which appeared in the journals and newspapers of this country; and so great was the success of the English Della Cruscan that in a short time Merry found a race of enthusiastic imitators, who flourished luxuriantly till Gifford, with the caustic satire of his *Baviad* and *Mæviad*, so ruthlessly blasted their growth. Merry went to America in 1796, and died at Baltimore two years afterwards. His dramatic pieces are,—*Lorenzo; The Magician no Conjuror; Fenelon;* and *Ambitious Vengeance.*

MERSEBURG, a town of Prussia, capital of a government of the same name, in the province of Saxony, is situated on the left bank of the Saale, 15 miles W. of Leipsic, and 56 S.S.E. of Magdeburg. The town is old and irregularly built; it is walled, and has four gates; and there are two suburbs, one of which stands on the other side of the river, and is approached by a stone bridge. Merseburg possesses a fine cathedral, built partly in the twelfth and partly in the fifteenth century, and containing many ancient monuments and one of the largest organs in Germany. The monument of Rudolph of Swabia in this cathedral, consisting of his figure in relief on a bronze plate, is believed to be one of the oldest specimens of mediæval art. The choir contains several paintings by Cranach. The castle of Merseburg, once the residence of the Dukes of Saxe-Merseburg, is a building of the fifteenth century, and is now occupied by the government offices. The town also possesses a monastery, situated in one of the suburbs, several Protestant churches, schools, a military hospital, and other establishments. The inhabitants are employed in the manufacture of linen and woollen fabrics, leather, paper, tobacco, vinegar, and beer; for which last Merseburg is famous. The trade of the town is considerable. The government of Merseburg has an area of 3994 square miles, and is in general low and undulating, with no eminences rising above the height of 1800 feet. The nature of the soil is various, but for the most part it is of considerable fertility; and the country is watered by the Elbe and its tributaries the Schwarze Elster from the E., and the Saale and Mulde from the W. Pop. of government (1855), 781,947; of the town, 11,264.

MERSENNE, MARIN, an eminent philosopher and mathematician, of the religious order of the Minimes, was born at Oysé in France in 1588, and studied at the college of La Flèche, where he made the friendship of Descartes, then a student at the same institution,—an intimacy which was kept up during their lives. He afterwards studied at the university of Paris and at the Sorbonne; and in 1613 he became a priest of the order of the Minimes. In his new sphere he commenced the study of the Hebrew language, and very soon mastered it. He held the philosophical chair of Nevers during the three years preceding 1619, when he became superior of the convent of his order in the neighbourhood of Paris. He afterwards travelled in Germany and Italy, and became acquainted during his visit to the latter country with the recent discoveries of Torricelli respecting a vacuum. Mersenne ultimately settled at Paris, where he died in 1648, lamented by a large circle of distinguished friends, who admired alike the gentle engaging manners of the man and the profound sagacity of the philosopher.

Some have ascribed to Mersenne the first discovery of the *cycloid;* an honour, however, to which he does no seem to be entitled. Some of the wits of his time affected to hold him in low esteem, and he was even charged with plagiarism by the Abbé Le Vayer, who calls him "*Le bon Larron;*" but it is a sufficient vindication of the Father's talents and character that the celebrated Descartes not only clung fast to him as a friend, but, as his correspondence amply testifies, consulted him on the most important points of his speculations. Mersenne's most famous work is the *Harmonie Universelle, contenant la Theorie et la Pratique de la Musique*, 2 vols., Paris, 1636-7. This work he afterwards translated into Latin, with important alterations and additions, rendering it almost an entirely new treatise, and entitled *Harmonicorum libri xii., de Sonorum Natura, Causis et Effectibus*, Paris, 1648, fol.

MERSEY, a river of England, is formed by the union of several small streams which take their rise in the hills near the borders of Yorkshire, Cheshire, and Derbyshire, where these three counties meet in a single point. The principal of these streams are the Tame and the Goyt; and from Stockport, where these two unite, the river thus formed takes the name of the Mersey, flows to the W., forming all along its course the boundary between Cheshire and Lancashire, and after a course from Stockport of 55 miles in length, falls into the Irish Sea below Liverpool. The principal tributaries of the Mersey are,—the Irwell, which flows past Manchester, and falls into the Mersey from the N., below the junction of which the river becomes navigable; and the Weaver, which joins it from the S. just before it expands into a large estuary. This estuary, which is 17 miles in length and 3 miles across at the broadest part, contracts at its mouth to a breadth of little more than three-quarters of a mile, so as to have the appearance, from several points of view, of a large inland lake. The country through which the Mersey flows is level; but in some parts the scenery is very picturesque. The principal towns and villages on its banks are,—Stretford, Warrington, Hale, Garston, and Liverpool, on the right bank; and Stockport, Runcorn, Ince, and Birkenhead, on the left.

MERTHYR TYDVIL or Tydfil, a parliamentary borough and market-town of South Wales, Glamorganshire, situated on the Taff, 22 miles N. by W. of Cardiff, and 171 W. by N. of London. The town, although it is said to be named after an ancient British martyr of the name of Tydvil, is entirely of modern origin, and consists chiefly of the cottages of workmen, meanly and irregularly built. Of late, however, the town has been much improved, and it now contains some regular and well-built streets, a court-house, a market-house, several elegant private residences, and a large number of excellent shops. The town contained in 1851 no fewer than 84 places of worship belonging to the following denominations:—Independents, 20; Baptists, 19; Church of England, 10; Wesleyan Methodists, 10; Welsh Calvinist Methodists, 10; Unitarians, 2; Primitive Methodists, 2; Wesleyan Reformers, 2; isolated congregation, 1; Roman Catholics, 1; Latter-day Saints, 6; Jews, 1. There were also at that time 68 Sunday schools, 16 public and 43 private day schools. The town has a library and reading-room, as well as several book-clubs;—all which facts afford evidence of the progress which the inhabitants are making in education and intelligence. Merthyr Tydvil, situated in a bleak and barren country, was at an early period known as a place for the smelting of iron ore, but it was never carried on to any great extent till Mr Anthony Bacon in 1755 obtained a lease of a district of land, 8 miles in length by 5 in breadth; and from that time may be dated the rise of the prosperity and importance of the town. Having erected extensive ironworks, and made a contract with the government for supplying the arsenals with cannons, he acquired an immense fortune, and finally disposed of the land in smaller portions to other individuals. From that time the works have gone on increasing in extent and in prosperity; and it is not difficult to account for the rapid rise of a large town in the vicinity, seeing that from 4000 to 5000 hands are employed in one establishment alone, and that upwards of L.1,000,000 is paid annually as wages in the four large ironworks in the district. There are now nearly fifty blast-furnaces in the vicinity of the town, producing annually from 150,000 to 200,000 tons of iron; which are for the most part conveyed by railway or canal to Cardiff, whence they are shipped to their various destinations. In the vicinity of Merthyr Tydvil there are numerous country seats, belonging principally to the wealthy proprietors of the different ironworks. Since the passing of the Reform Bill Merthyr Tydvil has returned one member to the House of Commons. The market-day is Saturday; and there are three annual fairs. Pop. (1851) of the borough, including the town of Dowlais, 63,080.

MERV, or Meru, a town of Turkestan, province of Khiva, situated on the caravan road between Meshed and Bokhara, about 12 miles E. of the Moorghab, and 300 S.E. of Khiva. The town was originally founded by Alexander the Great; but having been destroyed, it was rebuilt by Antiochus I., and received the name of *Antiochia Margiana.* The captive soldiers of Crassus were settled here by Orodes. In after times it was one of the four imperial cities of Khorassan, and many of the Persian monarchs made it their capital; but in 1786 it was taken and sacked by the Usbecks,—a blow from the effects of which it has never recovered. The surrounding country, which bears the name of Maroochak, was formerly celebrated for its fruits; but it is extremely unhealthy. The population is estimated at 3000.

MESHED, or Mushed, a town of Persia, capital of the province of Khorassan, is situated in a broad valley, 455 miles E. by N. of Teheran, and 500 N.E. of Ispahan; Lat. 36. 18. N.; Long. 59. 35. E. The town is surrounded by strong walls; but the houses are in general meanly built of brick, and nearly half of it is in ruins. The principal street, which passes through the town from E. to W., is wide and lined with handsome shops, and has a canal passing through its centre. The chief building is that which incloses the tombs of Imam Reza and of the Caliph Haroun Al-Raschid, on account of which Meshed is accounted a holy city, and visited by crowds of pilgrims. This edifice, which stands in the centre of the town, is a splendid building, with a gilt dome and two gilt minarets; possessing also splendid gateways and silver gates. Close to it stands a mosque, considered one of the finest in Persia, with a lofty blue dome and minarets. Besides this, the town contains a palace, which is an insignificant building hardly deserving the name; a large and well-supplied bazaar; and a caravansary, which is in an unfinished state. Meshed once had 16 medresses or colleges, but only a few of these now remain. The manufactures of the town consist of velvets, silks, jewellery, hardware, sword-blades, &c.; and there is a considerable trade carried on with Bokhara, Candahar, Herat, Yezd, &c. The position of the town on the great roads of Persia, and the numerous caravans continually passing, render Meshed a place of some importance as the emporium of the surrounding country. Pop. believed to be between 40,000 and 50,000.

MESJID, or Musjeed, Ali, a town of Asiatic Turkey, in the pashalic of Baghdad, is situated in a dry plain on the Euphrates, 90 miles S. by W. of Baghdad, and 28 S. of the ruins of Babylon. The town is well built, and surrounded by strong fortifications. The principal building is the mosque of Ali, containing the grave of the caliph of that name, visited by great numbers of pilgrims. Pop. about 6000.

Mesjid, or Musjeed, *Hossein*, a town in the pashalic of Baghdad, is situated about 50 miles S.W. of Baghdad, and 28 N.W. of Babylon. It derives its name from Hossein, the son of Ali, who is buried here in a mosque much venerated and frequented by Persian pilgrims. Pop. about 8000.

MESMER, Friedrich Anton, the author of the doctrine of *Mesmerism*, was born in 1734 at Marsburg in Baden. After attending the schools of Dillingen and Ingoldstadt, he studied medicine at Vienna, and subsequently settled in that city as a physician. It was there in 1766 that he gave the first rude outline of his theory in a treatise entitled *De Planetarum Influxu*. He founded his speculation on the supposition that there is an element of extreme subtlety which pervades the entire universe and permeates every body. He then asserted that this element, like the sea and the atmosphere, was influenced by the heavenly bodies, and that it communicated this influence to the nervous systems of all animals. In this way he accounted for the periodical affections of certain invalids. But this theory, in the form in which it was divulged, could not afford a basis for any art that might minister to the eager cupidity of its author. Mesmer therefore thought of making magnets perform the office of the heavenly bodies, and of using them to cure the diseases of the human frame. No sooner, however, had he begun the healing art than it appeared that a Vienna professor, Father Hell, had already been using magnets for the same purpose. A controversy ensued between the rival leeches touching their respective claims to the discovery. Mesmer was worsted; but effected a safe retreat from the contest by averring that he was not restricted to one instrument, for he could employ animal magnetism with the same effect as he had employed mineral. The efficacy of this new appliance he endeavoured by every means to prove to the public. He solicited the opinions of the Royal Society of London, the Academy of Sciences at Paris, and the Academy of Berlin. None of these bodies, except the last, deigned to give him even an unfavourable reply. As unsuccessful was his alleged cure in 1777 of Mademoiselle Paradis, a popular vocalist, who was suffering from *gutta serena* and convulsive affections in the eyes. The young lady was afterwards discovered to be as blind as ever; and Mesmer was obliged to flee from the punishment of his imposture. After practising his art for a short time in Germany and Switzerland, he repaired to Paris in 1778. At this time the French people, free from all political excitement and from all interest in foreign affairs, were ever on the alert for novelties and wonders. Accordingly, they received with eager curiosity the handsome and imposing foreigner who professed to unveil the secret workings of nature, and to effect a painless cure of all diseases by a simple process resembling the passes of a magician. Within a short time Mesmer had gained a great practice, had converted to his opinions Deslon, one of the faculty, and had published an account of his theory. Of this account many refutations by scientific men appeared. Mesmer condescended on one occasion to reply, and with cool self-complacency described himself as a man of genius and a benefactor of the human race. About the same time he was soliciting from the government a chateau and its lands as a reward for his services, and was threatening to leave France if they should attempt to cheapen the price of his labours. His request was not granted; but a life-rent of 20,000 francs per annum was offered to him. A yearly sum of 10,000 francs was also guaranteed, on the condition that he should permit three persons nominated by the ministry to inspect and report his proceedings. Mesmer was not pleased with the condition, and he put his former threat into execution by rejecting the offers of the French government, and by setting out with some of his patients to Spa. There his enthusiastic admirers, headed by Bergasse, promised to raise a subscription for his behoof if he would agree to reveal the secret of animal magnetism to all the subscribers. Mesmer grasped at the offer; and having returned forthwith to Paris, opened a spacious hall, and attracted all classes around him. In a luxuriously furnished room, pervaded by perfumes and echoing with soft music, he was wont to seat his patients round a species of magnetic battery called a *baquet*. When this co-operation of exciting causes began to produce as its necessary effect a nervous agitation through the entire circle, Mesmer appeared with his magic wand to regulate the action in each separate individual. So many cures were alleged to have been effected by this process, that at length, in 1784, the French government thought it their duty to examine into this apparent mystery. The proceedings of Deslon, the pupil of Mesmer, were accordingly scrutinized by a committee of inquiry consisting of the physicians Majault, Sallin, Darcet, and Guillotin, and the academicians Franklin, Leroi, Bailly, De Bory, and Lavoisier. The report, drawn up by Bailly, thoroughly exposed the falsehood and imposture of the Mesmeric process. About the same time the Royal Society of Medicine published another report equally condemnatory. These two testimonies from the scientific world were printed by the order of the government, and circulated throughout France. The disciples of animal magnetism attempted to check the advance of their enemies by forming themselves into societies. Mesmer, more politic, escaped amid the general confusion, carrying with him a subscription of 340,000 francs, and at the same time the secret for which that sum had been given to him. After living for some time in England under an assumed name, he repaired to Germany, and published in 1799 a new exposition of his doctrine. He died in obscurity in his native city in 1815.

MESOLONGHI, or Missolonghi, a town of Greece, in the government of Ætolia, is situated on the edge of a marshy plain on the N. shore of the Gulf of Patras, 22 miles W. of Lepanto. It is separated from the sea by a lake, 10 miles long and 5 in breadth, from which it probably derives its name, through the Italian *mezzo* and *laguna*. This sheet of water is so shallow, that there are few passages by which any but small boats can approach the town. Mesolonghi has a school, custom-house, and a small harbour. It is chiefly remarkable for the siege it sustained from the Turks in the Greek war. At the outbreak of the Greek revolution the place was indeed fortified, but the defences were in such an inefficient state from neglect, that it was necessary to increase and strengthen them in order to secure the safety of the town. The Greeks accordingly surrounded the city on the land side by a ditch, and a mound of earth and stones; but the approach of the Turks prevented any further improvements being made in the fortifications. In the beginning of 1825, by the arrival of Greeks from other parts of the country, and of volunteers from various nations of Europe, the garrison was raised to the number of 5000, who were commanded by Nothi Bozzaris; and on the 25th April of the same year a Turkish force of 20,000 under Reshid Pasha appeared before Mesolonghi. Nor was the inequality less, in the number and size of their artillery, between the besiegers and the besieged, than in the amount of their forces. On the 11th of May the first bombardment began, and for the space of two months afterwards the town was exposed to numerous bombardments and assaults; but the defenders were not less active in answering the enemy's fire, and making sallies from their defences, by which means they succeeded in repelling their assailants, and inflicting on them considerable loss. During this time they were supplied with ammunition and provisions by the fleet, which was stationed at the entrance of the lake; but on the 10th of July, a superior Turkish fleet, after compelling the ships of the Greeks to retire, succeeded in landing a strong reinforcement to the besiegers. The assaults on the town were then renewed with increased fury, and the cannonade of the Turks carried destruction to its frail ramparts, and death among the ranks of its brave defenders. Yet the garrison, though reduced to the number of 4000, continued to maintain their ground until, in the month of August, the Greek fleet appeared in the offing, and, by defeating the Turkish squadron, relieved Mesolonghi for a time from the blockade. But the sultan was resolved at all hazards to reduce this stronghold of liberty; and in the end of November, the Greek ships were again driven off, and the blockade renewed by the combined Turkish, Egyptian, and Barbary fleet. In the beginning of 1826 the besieging army was reinforced by the arrival of 14,000 troops under Ibrahim Pasha, who superseded Reshid Pasha in the command. On the 25th of January a bombardment was begun, which lasted for three days, and reduced the town to ruins, but could not shake the resolute courage of the Greeks. The repeated assaults of the enemy were still repulsed with great loss. At last, reduced to the utmost extremities by famine, and seeing on all sides nothing but the ships and tents of their enemies, yet never entertaining any thought of surrender, the Greeks determined to force their way through the opposing ranks, and thus convey themselves, with their wives and children, to a place of safety. Although by treachery the enemy was made aware of their design, and thus prepared to meet them, they were not able to prevent nearly 2000 of the besieged from making their way to the mountains. Many prisoners fell into the hands of the Turks, and the remainder, who were unable from their wounds or weariness to accompany their fellows, continued to defend themselves among the ruins until the explosion of a powder magazine, destroying alike friends and foes, put an end to the bloody conflict. Such was the siege of Mesolonghi, which attracted during its continuance the eyes of all Europe, and in which the Greeks showed themselves the worthy sons of the heroes of Marathon and Thermopylæ, and

> "Snatched from the ashes of their sires
> The embers of their former fires."

Near one of the gates of the town a mound of earth has been raised bearing an inscription in honour of those who fell in this famous siege. Lord Byron died at Mesolonghi on the 19th April 1824.

MESOPOTAMIA, an ancient country of Western Asia, was bounded on the N. by Armenia and Mount Masius, on the E. by the Tigris, on the S. by the Median Wall, and on the W. by the Euphrates. Its early name, as we learn from Scripture, was *Aram Naharaim* (Syria of the Two Waters), and was thus derived, like its after-name, Mesopotamia, from its peculiar position. The same cause has evidently induced the modern Arabs to call it *Al-Jezireh* (the Island). In addition to the Tigris and Euphrates, it is watered by the Chaboras (*Khabúr*), the Mygdonius (*Hermas*), and the Belas. Its principal towns were Nisibis (*Nisibin*), Edessa (*Orfa*), Circesium (*Karkesia*), and Carrhæ (*Harran*), the Haran of the Bible. According to Xenophon in his *Anabasis*, this country was a vast plain as level as the sea, diversified with no woods, abounding in sweet-scented wild-flowers, and haunted by wild asses, ostriches, buzzards, antelopes, and other animals; yet later writers represent it as affording rich pasturage for abundant herds, and possessing stately forests, especially on the banks of its two great rivers. Mesopotamia is seldom mentioned in history before the date at which it became a Persian province. Under the Romans it was divided into two parts,—Osrhoëne, on the W. of the River Chaboras, and Mesopotamia on the E. It was very impatient under the yoke of Rome, and continued to waver between revolt and submission until A.D. 363, when it was surrendered by Jovian into the hands of the Persians.

MESSALLA, CORVINUS MARCUS VALERIUS, a Roman general and orator, was born in 59 B.C. After studying at Athens he returned to Rome shortly after the death of Cæsar, and became the attached follower of Cassius. His name was accordingly inserted by the triumvirs in the list of those whom they devoted to death, but was afterwards erased at the petition of his friends. Refusing the proffered friendship of the triumvirate, Messalla followed the fortunes of the republican army, and stood next in command to Brutus and Cassius. On the field of Philippi he turned the flank of Augustus, stormed his camp, and was once on the point of taking him prisoner. The death of the two republican generals left him in charge of the shattered remains of their army. He effected a safe retreat to the island of Thapsos, and there he accepted honourable terms from Antony. Provident and politic, Messalla foresaw the downfall of Antony, and opportunely transferred his allegiance to Augustus. His military talents were successfully exerted in the service of the latter. He routed the Alpine tribe of the Salassians in 34 B.C., commanded the centre of the fleet at Actium in 31 B.C., and reduced the province of Aquitania in 27 B.C. For the last achievement he was honoured with a triumph on his return. Messalla had been appointed consul in 31 B.C., and was now, in 27 B.C., nominated prefect of the city. Shortly afterwards, however, he resigned all his public offices except his augurship. After suffering such a total derangement of his intellect that at times he forgot even his own name, he died about 11 A.D.

Of Messalla's many works—oratorical, historical, grammatical, and poetical—some of the titles alone remain. Yet a vague estimate of his literary merit may be formed from the testimonies of his contemporaries and successors. His works are eulogized by Seneca, Quintilian, and the two Plinies. The author of the dialogue *De Oratoribus*, attributes greater elegance and chasteness to his orations than to those of Cicero. Kind-hearted, and a lover of literature, Messalla employed his opulence and political power in aiding and encouraging literary men. He restored Tibullus to his estate, and loved to gather round his table such men as Horace, Varius, Pollio, and Mæcenas.

MESSANA, or MESSENE (*Messina*), an ancient town of Sicily, was, according to all authorities, of Chalcidic origin. Its first inhabitants were Chalcidians, according to Thucydides and Pausanias, from the colony of Cumæ in Italy, but, according to Strabo from Naxos in Sicily. The original name of the city was *Zancle* or *Dancle*, from the form of the harbour resembling that of a sickle. The date of its foundation is not known with any precision; but it was probably in the latter part of the eight century B.C.; and within the first 100 years of its existence, it had attained to such a degree of prosperity as to be able to send off two colonies on the N. coast of Sicily, Mylæ, and Himera, the latter of which rose afterwards to considerable importance. When the Ionians in Asia Minor were subdued by the Persians, and were compelled either to live in slavery or to leave their country, they were invited by the Messanians to settle on the coast of Sicily. This invitation was taken advantage of by the Samians, along with some other Greeks from Asia; but they having landed in Italy, were persuaded by Anaxilas, the tyrant of Rhegium, to make an attack on Messana during the absence of Scythes, the king of that city. This they accordingly did, and were successful; but although Scythes was unable to regain his dominion, the Samians were equally powerless to retain it; and were soon after deprived of their sovereignty by Anaxilas, who introduced into the city a large body of settlers from his own city, and changed the name of their new abode from Zancle to *Messana*, in memory of his mother-country in Greece. These events must have occurred between 493 and 476 B.C. After continuing for some time under the power of the Kings of Rhegium, the Messanians succeeded in 461 in throwing off the yoke of these monarchs, and establishing a republican form of government, under which they continued for some time to enjoy freedom and prosperity. In 396 B.C. a large Carthaginian army under Himilco landed in Sicily, and advanced along the northern coast to Messana, which they took and levelled to the ground. But in the next year the Carthaginians were defeated and expelled by Dionysius of Syracuse, who then proceeded to rebuild Messana, and to repeople it with the old inhabitants and with colonists from Italy and Messœnia. Soon after 289 B.C. Messana was seized by the Mamertini, or worshippers of Mamers, a band of mercenaries who had been brought from Italy by Agathocles, King of Syracuse, and had been discharged at the death of that monarch. They endeavoured, without success, to change the name of the city to *Mamertina*. The Mamertines were afterwards attacked by Hieron of Syracuse, and being unable themselves to hold out against his power, were only saved from destruction by the arrival of a Carthaginian force under Hannibal, the son of Gisco. But an alliance with Carthage was distasteful to a party among the Mamertines; who gaining the predominance in the state, applied for aid to the Romans against the Carthaginians. This request was readily acceded to, and thence arose the first Punic war, during the course of which Messana was taken by the Romans, and thus became the earliest dependency of that people out of Italy. The city was first an ally of Rome, and afterwards a municipium; but its subsequent history in ancient times is not remarkable for any great events.

MESSENE, the capital of Messenia in Greece, was founded by Epaminondas in 369 B.C. In the building of this city, which was situated at the foot of Mount Ithome, the Thebans, along with the Messenians and their other allies, took part, and the buildings and fortifications were finished after eighty-five days. As Messene was erected in order to enable the Messenians to regain their independence and form a check to the power of Sparta, which then threatened the liberties of Greece, the place was made one of great strength, being inferior in that respect to few Greek cities. The citadel of Messene, which is inclosed within the city walls, stands on Mount Ithome, an elevation 2631 feet in height, which was celebrated in the first and third Messenian wars for its defence against the Spartans. The town of Messene was situated in a hollow to the S.W. of the citadel, and having Mount Eva on the S.E., between which and Ithome the walls were carried along a narrow ridge. The whole circuit of the walls is about 6 English miles; and the town was probably made of such an extent in order to accommodate the inhabitants of the neighbouring country, who might take refuge here in time of war, as a great part of the inclosed area must have been quite unfit for building. A description of the town and its principal edifices is given by Pausanias; and Strabo mentions the resemblance between the rock of Ithome and that of the citadel of Corinth. The town continued to exist until towards the end of the Roman Empire; but after that time it fell into decay, and the site is now partly occupied by the modern village of Mauromati, near which many remains are yet to be seen of the ancient buildings and walls.

MESSENIA, one of the ancient divisions of the Peloponnesus in Greece, was bounded on the N. by Elis and Arcadia, on the E. by Laconia, on the S. by the Messenian Gulf, and W. by the Ionian Sea. The area of the country is estimated by Clinton at 1162 square miles. The principal mountains in Messenia are those in the N., near the sources of the Neda and Pamisus, from which one ridge extends to the W. along the Neda, turns to the S., and terminates at the promontory of Acritas; and another chain of mountains stretches E., and joins the ridge of Taygetus. Its chief rivers are the Pamisus (*Pirnazza* and the Neda (*Buzi*). The cities worthy of notice were —Messene, Stenyclarus, Ithome, and Ira, all inland; Corone (*Petalidi*), on the Messenian Gulf; and Methone (*Modon*), Pylos, and Aulon, all on the Ionian Sea. Messenia is described by ancient writers as having a rich and fertile soil, and a mild and temperate climate; and modern travellers confirm the remark of Pausanias, who calls Messenia the richest country in the Peleponnese. This country is said to have been first inhabited by the Leleges under Polycaon, the son of Lelex, who called it *Messenia*, after his wife Messene. After more than a century the country came into the possession of Æolians under Perieres, son of Æolus, and the western part was occupied by Neleus, an Æolian from Thessaly. When the Dorians conquered the Peloponnese, Messenia fell to the lot of Creophontes, who established his capital at Stenyclarus, and divided his kingdom into five parts. Soon afterwards, however, the richness and fertility of Messenia excited the cupidity of the Spartans, and after numerous disputes and incursions on both sides an open war at length broke out, which is known in Greek history as the first Messenian war. This war lasted for twenty years (743–723 B.C.), and during its continuance the Messenians under Aristodemus defended themselves against the Spartans in the fortress of Ithome; but this was finally taken by the Spartans, and the Messenians became helots or slaves of the conquerors. After remaining for some time in this condition, they made an effort to regain their independence in 685 B.C.; and thus began the second Messenian war, which lasted till 668 B.C. The leader of the Messenians on this occasion was Aristomenes; and it was in this war that the Spartans received the assistance of Tyrtæus from Athens, to animate by his warlike songs the courage of their soldiers. When their country was a second time subdued by the capture of Ira, a large body of Messenians fled from their country, and settled, partly at Rhegium in Italy, and partly in various parts of Greece. Others remained at home, and became helots. Another attempt was made by them to regain their freedom in 464 B.C., when Sparta was destroyed by an earthquake. In this third war the fortress of Ithome was again occupied by the Messenians; but after a contest of ten years was surrendered to the Spartans. In 455 B.C. the Messenians were allowed by the Spartans to retire from their fortress, and were settled by the Athenians in Naupactus, a town which the latter had recently obtained from the Locrians. From this place the Messenians were expelled in 404 B.C., at the end of the Peloponnesian war; but they were restored to Messenia by Epaminondas in 389 B.C., where they continued independent until the conquest of Greece by the Romans in 146 B.C..

MESSIAH. See CHRIST, and JESUS.

MESSIER, CHARLES, a skilful astronomer, born at Badonviller in Lorraine, on the 26th of June 1730. He came to Paris at the age of twenty to seek his fortune. Having learned to write a good hand and to draw, Delisle employed him as a copyist in the observatory, and Libour, his secretary, taught him to make use of the common instruments of astronomy, to observe eclipses, and to look out for comets, which was the principal business of his subsequent life, for he was never much of a theoretical or philosophical astronomer. Delisle obtained for him a clerkship in the hydrographical department of the navy, previous to his appointment as astronomer to the admiralty.

After having discovered twelve comets, he obtained a seat in the academy in 1770. He had afterwards the honour of being made an academician of Berlin; and through Laharpe's interest he obtained the same distinction from St Petersburg. He was also made a fellow of the Royal Society of London in 1764. The highest compliment that he ever received was paid him, perhaps without sufficient reason, by Lalande, who inserted in his celestial globe of 1775 a constellation with the name of *Messier*, or *Messium custos*, in the neighbourhood of Cepheus. When Herschel had discovered the Georgian planet, Messier was very diligently engaged in observing its motions; but his studies were unfortunately interrupted by an accident, from the effects of which he was long of recovering. He received a pension on this occasion from the royal bounty, of which, however, he was soon after deprived by the Revolution. Messier was in some measure compensated for his pecuniary losses by being made a member of the Institute, of the Bureau des Longitudes, and of the Legion of Honour. He died on the 11th of April 1817.

A variety of his observations, especially of Comets, are published in the *Mémoires des Savans étrangers*, v. vi., and in the Memoirs of the Academy from 1771 to 1790. There is also a *Catalogue of Nebulæ* in 1771; *An Account of Points of Light seen on Saturn's Ring* in 1774; and of *An Apparent Fall of Globules over the Sun's Disc*, 1777. He also contributed some articles to the *Connaisance des Temps* and to the *Astronomical Ephemerides*.

MESSINA, a town and seaport of Sicily, capital of a province of the same name, is situated at the N.E. corner of the island, on the Straits of Faro or Messina, here about 4 miles in breadth, 8 miles N.W. of Reggio, and 120 E. by N. of Palermo; Lat. (of lighthouse) 36. 18. N., Long. 59. 35. E. The appearance of Messina from the sea is very grand and beautiful. The town is built on the slope of a hill in the form of an amphitheatre, behind which rise mountains covered with dark forests, which heighten by contrast the beauty of the white buildings in the town. The greatest part of the town is built on the W. side of the harbour; the streets are broad and well paved with lava, and the houses are handsome, and in general two storeys high. The town is defended by walls and bastions, as well as by a citadel and numerous forts; so that Messina is reckoned a first-rate fortress. Among the principal buildings in Messina there are about 50 churches, the most remarkable of which is the cathedral, in the Gothic style, built shortly after the Norman conquest of Sicily. The nave of this edifice is supported by ancient granite pillars, which were formerly a part of a temple of Neptune. The altar and the roof of the choir are of mosaic work, and the pulpit is adorned with very beautiful carved work by Gaggini, the Sicilian sculptor; but the general appearance of the building is heavy and tasteless. There are numerous convents and nunneries in the town. The palace of the viceroy is a very fine building, and has a large open space laid out in gardens and walks. Besides these, there are an archbishop's palace, senate-house, college, public library, hospital, lazaretto, two theatres, &c. The harbour of Messina, which is the best in Sicily, is formed by a narrow strip of land in the form of a sickle, which incloses it on all sides but the N., where there is an entrance about 700 yards in breadth. It is thus somewhat difficult of access, but when once entered, it is large and deep. Men-of-war can anchor in the harbour; while merchant vessels come alongside of the quay. The position of the town and the excellence of the harbour give Messina great importance in a commercial point of view. The exports of the place consist principally of oranges, lemons, currants, raisins, wine, brandy, oil, liquorice, sheep and goat skins; and the chief imports are cotton and woollen stuffs, sugar, coffee, hides, and hardware. The inhabitants are also employed to a large extent in the tunny, coral, and other fisheries. The principal manufacture is that of silk stuffs, especially damasks and satins. Messina was almost entirely destroyed by an earthquake in 1693; and in 1743 was visited by the plague, supposed to have been conveyed thither by a vessel from the Levant. Afterwards, in 1780 and 1783, the town was again exposed to the calamities of earthquakes, and on the last occasion was more than half destroyed; since which time it has been built in a much superior style. In 1848 Messina, along with the other large towns of Sicily, went with the popular party, and was bombarded by the Neapolitan fleet. After a bombardment of four days, in which a large part of the city was laid in ruins, it was compelled to surrender.

The province of Messina is bounded on the N. by the Mediterranean, E. by the Straits of Messina, S. by the province of Catania, and W. by that of Palermo; and is 60 miles in length by 30 in breadth. It is occupied in the interior by the mountain range which traverses the N. of Sicily; and though destitute of large plains, it has many valleys, some of which are very rich and fertile in wine, oil, and fruits of various sorts. Pop. of the town (1850), 97,074; of the province (1854), 380,279.

MESTRINO, Nicolo, a famous violinist and excellent composer, was born at Milan in 1748, as is proved by his letter, dated at Brussels 18th August 1786, and addressed to the then governors of the Netherlands, to whom he applied for the vacant post of their master of music. They bestowed the place upon Witzthumb, a native of Baden, who had been long employed as a musician at the court of Brussels. At that time Mestrino had been in the service of Prince Esterhazy, and next of Count Ladislas Erdoedy, as first violin; and had travelled in Italy, Germany, and other countries, with a high musical reputation. Disappointed in his views at Brussels, he proceeded to Paris, where he played one of his concertos at the Concert Spirituel on the 17th December 1786. His extraordinary skill attracted immediate attention, and he was appointed leader of the orchestra of the chief theatre; and, in 1789, director of the excellent orchestra that had been formed by Viotti for the Italian Opera at Paris. He died in September 1790. The late celebrated contrabassist Domenico Dragonetti assured the writer of this article that Mestrino was the best violinist he had ever heard. One of Mestrino's effects in playing was the *slide* performed with the same finger on the same string in passing from one sound to another, a 3d, 4th, or 5th, &c., higher or lower. An example of this is given at page 43 of the second edition of Woldemar's *Grande Méthode pour le Violon*. Mestrino trained several good pupils, and among these, Mademoiselle de la Jonchère, afterwards known as Madame Ladurner. When he arrived in Paris and attracted public attention, the circumstances of his previous artistic life were not known; and thence arose false and absurd stories, invented against him by persons who were jealous of his superiority. It was said that he had long been a street-fiddler, that he had been imprisoned, and had practised the violin incessantly during his confinement: stories utterly destitute of foundation. The late celebrated violinist Paganini was assailed by similar stories, and even by atrocious imputations of murder: all mere fabrications of jealousy. The genuine works of Mestrino, which were published at Paris, consist of twelve Concertos for a principal violin and orchestra; four sets of Duets for two violins; Studies and Caprices for a violin alone; Sonatas for a violin and bass. (G. F. G.)

METAPHOR, a species of rhetorical trope founded on the resemblance which one object bears to another. It is in reality only comparison or simile expressed in an abridged form. For example, the sentence,—"These men are lambs in the family, but lions in the field," is an example of metaphor; but to say, "These men are *like* lambs in the family, &c.," is an instance of simile or comparison. In short, the peculiar distinction between these two figures is, that in simile we say one object is *like* another, while in metaphor we drop the word expressing the similitude, and say one object *is* another. And hence the peculiar boldness which characterizes metaphor, and which is not to be found in the same degree in any of the figures of rhetoric. Those ordinary metaphors which long use has sanctioned have a tendency, in all languages, to sink to the level of common terms.

METAPHYSICS.

Introduction.

Among the various changes which the language of philosophy has undergone in the gradual progress of human knowledge, there is none more remarkable than the different significations which, in ancient and modern times, have been assigned to the term Metaphysics—a term at first sight almost equally indefinite in its etymological signification and in its actual use. As regards the origin of the name, the most recent discussions appear on the whole to confirm the commonly received opinion, according to which, the term *Metaphysics*, though originally employed to designate a treatise of Aristotle, was probably unknown to that philosopher himself. It is true that the oldest and best of the extant commentators on Aristotle refers the inscription of the treatise to the Stagirite;[1] but in the extant writings of Aristotle himself, though the work and its subject are frequently referred to under the titles of the *First Philosophy*, or *Theology*, or *Wisdom*,[2] no authority is found for the latter and more popular appellation. On the whole, the weight of evidence appears to be in favour of the supposition which attributes the inscription τὰ μετὰ τὰ φυσικά to Andronicus Rhodius, the first editor of Aristotle's collected works. The title, as given to the writings on the first philosophy, probably indicates only their place in the collection, as coming *after the physical treatises* of the author.[3] In this respect, the term *Metaphysics* has been aptly compared to that of *Postils;* both names signifying nothing more than the fact of something else having preceded.[4]

The title, thus indefinite in its etymological signification, does not at first sight appear to admit of more precision with reference to its actual application. Mr Stewart, towards the end of his dissertation on the progress of metaphysical and ethical philosophy,[5] notices "the extraordinary change which has gradually and insensibly taken place, since the publication of Locke's Essay, in the meaning of the word *Metaphysics;* a word formerly appropriated to the ontology and pneumatology of the schools, but now understood as equally applicable to all those inquiries which have for their object to trace the various branches of human knowledge to their first principles in the constitution of our nature." "This change," he continues, "can be accounted for only by a change in the philosophical pursuits of Locke's successors; a change from the idle abstractions and subtleties of the dark ages, to studies subservient to the culture of the understanding; to the successful exercise of its faculties and powers; and to a knowledge of the great ends and purposes of our being. It may be regarded, therefore, as a palpable and incontrovertible proof of a corresponding progress of reason in this part of the world."

This change in the pursuits, and consequently in the language, of philosophy had been noticed shortly before by a philosopher of another country in a very different spirit. Hegel, in 1816, introduced his lectures on the history of philosophy in the following words:—"In the other countries of Europe, in which the sciences and the cultivation of the understanding have been prosecuted with zeal and credit, every remembrance and trace of philosophy, the name only excepted, has perished and disappeared. Among the Germans alone, it has maintained itself as a national possession. We have received from nature the higher mission to be the preservers of this sacred fire, as the Eumolpidæ of Athens were intrusted with the preservation of the Eleusinian mysteries."[6] Between these opposite conceptions of metaphysics or philosophy (for in the language of Hegel, the two terms may be regarded as synonymous), it is not easy for an expositor to select his point of view. A definition of metaphysics which would include both, would be defective philosophically from its vagueness: one which would exclude either, would be defective historically from its incompleteness. To omit the view indicated by Hegel would be to neglect the whole of the ancient and a great part of the modern history of the science. To omit the view indicated by Stewart would be to overlook almost entirely the important share which the writers of our own country have contributed towards the solution of the great problem of philosophy. Yet the reader who has perused a few pages of Aristotle's *Metaphysics* or the later works of a cognate character, on the one hand, and of Locke's *Essay* or Stewart's *Elements*, on the other, will probably be at a loss to conjecture what possible common notion can be found to unite together works so utterly distinct in their aim and method. A few preliminary observations on this point may, it is hoped, in some degree assist in throwing light on this obscure and almost imperceptible link of connection.

Speculative philosophy is divided by Aristotle into three branches—physics, mathematics, and theology. The first investigates the special attributes of this or that body as such; the second considers the properties of bodily figures abstracted from their material accompaniments; the third contemplates pure existence, apart from the sensible accidents of matter or figure.[7] This division, however, is one which could not have been made until after philosophy had attained to some considerable development. In the earlier stages of its history, philosophy in general would naturally be identified with one or other of the above branches only, according as its first cultivators sought to explain the principles and causes of things by means of this or that fundamental assumption. Hence it is, that while the history of *philosophy* in its widest sense opens with inquiries identical in their aim with those afterwards pursued by the metaphysician, the history of *metaphysics* proper can hardly be said to have commenced until the progress of thought and the failure of previous speculations led men to attempt the solution of the general problem of philosophy in a particular manner.

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[1] Alexander *in Arist. Metaph.*, B. (p. 127, ed. Bonitz).

[2] Asclepius, apud Brandis, *Scholia*, p. 519, b. 19. Bonitz *in Arist. Metaph.*, p. 5.

[3] "Titulum vulgatum τὰ μετὰ τὰ φυσικά non ab ipso esse Aristotele his libris inscriptum, adeo est verisimile ut pro certo haberi possit. . . . Ad ordinem librorum hanc inscriptionem referri, ut libri de prima philosophia excipere significentur libros physicos, communis fere est ac verissima interpretum Græcorum sententia." Bonitz *ad Arist. Metaph.*, pp. 3, 5. M. Ravaisson, on the other hand, is of opinion that the name should be referred to Aristotle himself, or to one of his immediate disciples.

[4] Cardwell's preface to Taverner's *Postils.*

[5] See *ante*, vol. i., p. 227.

[6] *Hegel's Werke*, vol. xiii., p. 4. English philosophy, name and thing, is especially honoured with the contempt of this critic. "The natural sciences," he says, "are in England denominated Philosophy. An English *Philosophical Journal* treats of chemistry, agriculture, and manure, of housekeeping and professional knowledge, and communicates discoveries in these departments. The English call physical instruments, such as the barometer and thermometer, philosophical instruments. Theories, especially in morals and moral sciences, which are derived from the feelings of the human heart or from experience, are called Philosophy, as well as those which contain principles of political economy. Thus the name at least of Philosophy is honoured in England." *Ibid.*, p. 72. See also vol. vi., p. 13. In the same spirit are dictated his criticisms on Bacon, Locke, and Newton; the latter of whom, he says, has exhibited in his Optics a perfect specimen of the manner in which experiment and reasoning should not be conducted.

[7] *Metaph.* v. 1. See also *De Anima*, i. 1. The distinction may be illustrated by an example. Suppose the object of contemplation to be a wooden square; the physical philosopher considers it *quâ* wooden; the mathematician, *quâ* square; the theologian or metaphysician, *quâ* something which exists.

Philosophy in general may be defined, as nearly as a conception so vague admits of definition, as an inquiry into the principles and causes of things.[1] Metaphysics has been defined by Aristotle (and the definition may be for the present provisionally accepted), as the science which contemplates being as being, and the attributes which belong to it as such.[2] The latter definition, while verbally resembling the former, exhibits, in fact, an important modification of it; for it implies that the progress of philosophy had necessitated the division of things in general into beings, or things as they are, and phenomena, or things as they appear. The material principles assumed by the Ionians and the mathematical relations of the Pythagoreans were theories of the universe, falling under the general conception of philosophy; but the origin of metaphysics must rather be dated from the period when the Eleatics denied the reality of the sensible world, and confined the region of truth to the supersensible unity which can be obtained only by contemplation.[3]

Philosophy becomes synonymous with metaphysics in the view of those philosophers who regard thought alone as the channel by which men can attain to reality and truth—a point of view which predominates in the speculations and language of ancient Greece and of modern Germany. Our own countrymen have for the most part erred in the other extreme, and limited the province of philosophy too exclusively to the investigation of the phenomena of sense. And the result has been that, while in Britain the name of metaphysics has been rescued from contempt only by an abuse of language which identifies it with a branch of inductive science, in Germany it is not unusual to represent the country of Bacon, Newton, and Locke, as one which has produced no philosophy.

The first step towards a definite conception of metaphysics was attained by regarding it as *the science of real existence*. But this conception, like the wider one of philosophy in general, becomes in its subsequent process developed from different and even contradictory points of view, till the resulting systems appear to have nothing in common but the name. The notion of being, as distinguished from phenomenon, corresponds in its original signification with that which the mind conceives as permanent and unchangeable, in opposition to that which is regarded as transitory and fluctuating. Such an object of inquiry may be approached from two opposite sides. It is the real in itself, and it is contemplated by the mind as such. The problem has thus a twofold aspect, as related to the conditions of being and to the conditions of thought; and its solution may be attempted from the one or the other starting point. We may commence with abstract principles of being in general, and endeavour to deduce *à priori* the essential characteristics of existence *per se;* or we may commence with an examination of the actual constitution of the human mind, and endeavour to ascertain empirically how the conception of reality is formed, and what is its consequent value. And either of these methods of inquiry may be so conducted as in the end to lose sight of the original relation which binds them together; and each may thus present an aspect of irreconcilable antagonism, in place of the mutual pursuit of a common object. The *à priori* reasoner may pervert his conception of absolute being into a form which finds no counterpart in the human consciousness, and, confident in the infallibility of his own process, may condemn as worthless the mirror which refuses to reflect back the distorted image. And the investigator of the facts of consciousness, when his imperfect analysis has failed to discover the hidden element of reality, may proclaim reality itself to be a dream and a delusion, and the mind and all that it contains a mere aggregate of phenomena. Deceived by the apparent parallelism of the distant rays, the opposing theorists forget that those rays must converge somewhere in a common centre: they forget that philosophy itself is but the articulate development of consciousness; that from consciousness all inquiries set out, and to consciousness they must all return.

And such, history tells us, has been the actual fate of metaphysics. The clue to its distant mazes, lost almost at the outset of the journey, became more and more irrecoverable as the paths diverged more and more from their common centre; till its latest expositors on both sides were unconscious of its existence. If Aristotle for a moment grasped the important truth, that the laws of things and the laws of thought were alike objects of metaphysical inquiry,[4] the conviction produced hardly any result in the details of his treatment: his psychology allied itself chiefly to physics; his metaphysics, after its introductory chapter, deserted the track of psychology. If Locke laid the foundation of a better method of metaphysical inquiry when he declared, that "before we set ourselves on inquiries of this nature, it was necessary to examine our own abilities, and see what objects our understandings were or were not fitted to deal with,"[4] he prematurely excluded the very question which his method was required to solve, by asserting that we have no ideas of body or spirit as substances, but merely suppose an unknown substratum to our external or internal ideas.[6] The barrier thus interposed between the sister streams of thought was widened as each flowed on: the ontological philosophers of modern Germany gloried in being not merely independent of, but even contradictory to, the testimony of consciousness; while the psychological teachers of France and Britain confined themselves more and more within the charmed circle of phenomena, till D'Alembert declared that the office of metaphysics was to prove that all our ideas come from sensation;[7] and Stewart denounced the inquiries of ontology as "the most idle and absurd speculation that ever employed the human faculties."[8] But the principle on which this conclusion logically rests is, as regards the Scottish philosophy, an excrescence rather than an integral portion of the system. We may refuse to admit the unproved dogma which denies to the human mind any conception of substance, and yet avail ourselves of the psychological researches of Reid and Stewart, as a valuable, if an incomplete contribution to

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[1] Arist. *Metaph.* i. 1. Τὴν ὀνομαζομένην σοφίαν περὶ τὰ πρῶτα αἴτια καὶ τὰς ἀρχὰς ὑπολαμβάνουσι πάντες. See also Hobbes, *Computatio sive Logica.* chap. 1, sect. 2.

[2] *Metaph.* iii. 1. Ἔστιν ἐπιστήμη τις ἣ θεωρεῖ τὸ ὂν ᾗ ὂν καί τὰ τούτῳ ὑπάρχοντα καθ' αὑτό.

[3] Arist. *Metaph.* v. i. Εἰ μὲν οὖν μή ἐστί τις ἑτέρα οὐσία παρὰ τὰς φύσει συνεστηκυίας, ἡ φυσικὴ ἂν εἴη πρώτη ἐπιστήμη· εἰ δ' ἐστί τις οὐσία ἀκίνητος, αὕτη προτέρα καὶ φιλοσοφία πρώτη.

[4] *Metaph.* iii. 3. Ὅτι μὲν οὖν τοῦ φιλοσόφου καὶ τοῦ περὶ πάσης τῆς οὐσίας θεωροῦντος ᾗ πέφυκεν, καὶ περὶ τῶν συλλογιστικῶν ἀρχῶν ἐστὶν ἐπισκέψασθαι, δῆλον.

[5] *Essay*, Epistle to the Reader.

[6] *Essay*, b. ii., ch. 23.

[7] "La métaphysique a pour but d'examiner la génération de nos idées, et de prouver qu'elles viennent toutes de nos sensations." (*Elém. de Philos.*, p. 143; *Melanges*, vol. iv. (quoted in Sir W. Hamilton's edition of Stewart's Works, vol. i., p. 404.)

[8] *Philosophical Essays*, Preliminary Dissertation, ch. i.

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the philosophy of consciousness, and, through that, to the solution of those fundamental problems of metaphysics to which consciousness gives rise.

As the metaphysical writings of Aristotle and his followers are likely to be but little known to the majority of modern readers, it may be useful to add a brief account of the ancient method of treating the subject, which will serve at the same time to exhibit more clearly the chasm which separates the earlier conception of the science from that of the modern disciple of Locke or Stewart. "There is a certain science," says Aristotle, "which contemplates being in so far as it is being, and the attributes that belong to it essentially as such. This science is not the same with any of those which are called particular sciences; for none of these inquires generally concerning being as being, but each selects some separate portion of being, and contemplates the properties of that alone; as, for example, mathematics. But since we are seeking for the principles and highest causes of things, it is clear that these must have some nature to which they properly belong. We must therefore take as the object of our inquiry the first causes of being as being."[1]

A similar conception of the great problem of philosophy had been previously exhibited by Plato in his sketch of the office of dialectic—a science which, though differing in name and method, is in its purpose and aim identical with the first philosophy or theology of Aristotle. In the sciences of geometry and arithmetic, he tells us, certain principles of numbers and figures are assumed by hypothesis as self-evident, but not investigated by any process of reasoning; and from these assumptions the proposed questions are demonstrated. But in dialectic the same hypotheses are employed, not as first principles, but as stepping-stones to some higher truth and absolutely first principle, which is grasped by the intellect without hypothesis, as that on which all other reasoning ultimately depends.[2]

The problem of metaphysics, as conceived by both these philosophers, may be perhaps more clearly stated in modern language as follows:—"To determine the relation that exists between the subjective necessities of thought and the objective necessities of things." In mathematical demonstration, for example, we start from certain axiomatic principles, of which, as mathematicians, we can give no other account than that they are *self-evident;* that is to say, that we are compelled by the constitution of our minds to admit them. But this opens a further question. What is the relation of self-evidence to reality? Is the necessity, of which I am conscious, of thinking in a certain manner any sure guarantee of a corresponding relation in the objects about which I think? In other words, are the laws of thought also laws of things; or, at least, do they furnish evidence by which the laws of things can be ascertained? Is thought identical with being, so that every mode of the one is at the same time a mode of the other? Is thought an exact copy of being, so that every mode of the one is an adequate representative of some corresponding mode of the other? Or, finally, is thought altogether distinct from being, so that we cannot issue from the circle of our ideas, to seize the realities which those ideas are supposed to represent? Does anything exist beyond the phenomena of our own consciousness? and, if it does exist, what is the path by which it is to be reached?

The ancient and mediæval metaphysicians adopted almost unanimously the *à priori* method of reasoning downwards from the assumption of abstract principles of being,—as the moderns have laid the foundation of the inverse method of reasoning upwards from the phenomena of thought. A short analysis of the principal subjects treated of in the *Metaphysics* of Aristotle will serve to exhibit the details of the former method, as far as our present limits will permit. In the order of the books we shall follow the common arrangement, which, though far from unexceptionable, is perhaps not more liable to objection than others which have been proposed in its place.

The first book comprises a psychological account of the nature of science and its origin in the human mind, followed by a history of the researches of previous philosophers into the principles and causes of things. To this is subjoined a kind of appendix (the book known as *A minor*), containing an argument in favour of the existence of a first principle of things, and consequently of the possibility of attaining to a knowledge of it; with a caution concerning the method to be pursued, and the necessity of accommodating the mode of reasoning to the nature of the object.

The second book commences with a list of questions, which are to be answered in the course of the treatise, and which may be regarded as furnishing a sort of table of contents to the rest of the work.[3] They may be briefly summed up as follows:—1. Do the principles of being and those of demonstration belong to the same or to different sciences, to one science or to many? 2. Are there other substances besides objects of sense; and, if so, of how many kinds? 3. To what science does it belong to take cognisance of identity and difference, similarity and dissimilarity, priority and posteriority, and such like? 4. Are the principles of things to be sought in their genera, or in the material elements of individuals, or does there exist a cause or causes other than matter, and separable from it? 5. Are there the same principles of things perishable and imperishable, and are all principles themselves imperishable? 6. Are being and unity the essence of all things, or must other elements be added? 7. Are the principles of things universal or individual, potential or actual, active or passive? 8. Are numbers, lines, figures, and points substances or not; and, if substances, do they exist separate from the objects of sense? A further development of the difficulties involved in these questions occupies the remainder of this book.

The third book is occupied with the sketch of a science of being as such, which has for its object both the principles of things and the laws of reasoning. In it the philosopher maintains the truth of the logical principles of contradiction and excluded middle against the objections of Heraclitus, Anaxagoras, and others, and establishes the distinction between being and appearance, and consequently between truth and error.

The fourth book is an explanation of the various significations of several philosophical terms. The terms defined are,—principle, cause, element, nature, necessity, unity, being, substance, identity, distinctness and diversity, similarity and dissimilarity, opposition and contrariety, priority and posteriority, power, quantity, quality, relation, perfection, limitation, in respect of and in itself (*καθ' ὃ* and *καθ' αὑτό*), disposition, habit, passion, privation, possession, derivation, part, whole, imperfection, genus, falsehood, accident.

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[1] *Metaph.* iii. 1. The same view is also exhibited more fully in v. 1, in a passage too long for quotation.

[2] *Republic*, vi., p. 510.

[3] The correspondence, however, is by no means exact. Michelet observes,—"En général, il faut remarquer ici que l'énumération et le développement des problèmes contenus dans ce livre ne répondent pas exactement à leurs solutions donneés dans les autres livres. Car beaucoup de problèmes sont transposés; quelques-uns n'y sont qu'effleurés; plusieurs y sont réunis, à cause de l'affinité qu'il y a entre eux; d'autres enfin sont traités en différents endroits." (*Exam. Critique*, p. 131.) The division of the questions themselves admits of considerable variety. Michelet and Ravaisson enumerate as many as seventeen. Mr Maurice (*Moral and Metaphysical Philosophy*, p. 183) reduces them to six.

The fifth book continues the sketch of a science of being which was commenced in the third. This science (called by Aristotle "Theology," and afterwards known as Metaphysics) is distinguished from physics and mathematics. Being *per se*, the proper object of metaphysics, is distinguished from other senses of the term,—such as accidental existence, which is not an object of science, and truth in judgments, which belongs to thought and not to things.

The sixth book is a continuation of the same subject. Being, in the highest sense of the term, is identified with substance, to the exclusion of the other categories. But substance, again, is used in various senses; sometimes for the essence of a thing, sometimes for its universal attributes, sometimes for the genus, sometimes for the subject of attributes, or the individual. A discussion of these different senses, and of the philosophical theories connected with them, occupies the remainder of the book.

The seventh book continues the discussion of substance. The essence of sensible things may be considered in two points of view,—as regards the *matter* or potential essence, and as regards the *form* or actual essence, corresponding to the genus and difference in a definition. The unity of such objects must be sought for in the principle which unites these two. Intelligible objects, which have no matter, are one by virtue of their form.

In the eighth book the distinction between matter and form, or potential and actual existence, is further discussed. The distinction between the potential and the actual is defended against objections. The actual is prior to the potential in the order of nature and of reason, and, in one sense, in that of time also. It is prior in the order of reason; for power has no meaning but in relation to performance. It is prior, too, in the order of time in the species, though not in the individual; for the powers of any thing are produced by its efficient cause, and the cause, as such, is in action. Hence it follows, that the distinction between the potential and the actual exists only in relation to things perishable; for that which is eternal cannot have become what it is, and therefore can never be potentially that which it is not actually. In other words, there is a cause of change which itself acts unchangeably, and which is prior to all change. The chief good and highest principle is thus ever active, and there is no eternal principle of evil; for actual evil is a corruption posterior to the possibility of evil. The book concludes with a discussion of the nature of truth and falsehood; the latter of which can have no place in relation to first principles, which must either be absolutely known or absolutely unknown.

The ninth book is a digression, treating of the opposition between the one and the many. The various senses of unity enumerated in the fourth book are now reduced to four,—the continuous, the whole, the individual, and the universal. Unity is identified with existence, and declared, in opposition to the Pythagoreans and Platonists, to be not a substance, but an universal notion predicable of every kind of subject in the several categories. The opposition between unity and plurality is shown to be not one of contrariety, but of relation. The book concludes with a further digression on some points connected with the opposition of contraries.

In the tenth book, as well as in the ninth, the connection of the argument is somewhat interrupted. This book, in fact, contains little more than a recapitulation of matters treated of in some of the earlier books. The concluding chapters of this book are an abridgment of a portion of the *Physics* of Aristotle, and appear altogether out of place in their present position.

The eleventh book is the most important of all; and though apparently incomplete in itself and in its connection with its predecessors, may be regarded as containing an outline of Aristotle's views on the profoundest problems of metaphysical philosophy. In this book, after some preliminary remarks on the nature of substance, change, and causation, the philosopher resumes his inquiry into the nature of the first cause—the unchanging principle of all change and motion. Sensible substances, the objects of physical science, are subject to change; and all change implies a progress of the same subject from one of two opposite states to the other; from not being to being, or the reverse. Hence change implies three elements: the form, the privation, and the matter potentially susceptible of both. But change itself must take place in consequence of some cause; we must, therefore, add a fourth principle to the three elements. We are thus led to the notion of a substance which is the efficient cause of change, and this substance must be eternal; for even change and time are conceived as imperishable, and these depend upon a substance. The cause of change must therefore be a being eternally acting, and which, consequently, cannot be conceived as having a power to act prior to the exercise of that power. In other words, the first cause (as was said before in the eighth book) can never be potentially that which it is not actually. The first cause is thus active without being passive; it moves all things without being itself moved. The action of an unmoved cause of motion may be regarded as analogous to that of an object of desire on the appetite, or of an object of contemplation on the intellect; for these excite to action without being themselves acted upon. Thus the principle of change may be conceived both as first cause and as final cause or chief good, which all things desire, and by the desire of which they are moved.[1] This first cause is God, who, as the highest object of intellectual contemplation, must himself be conceived as Intellect, as ever active, as living (for the activity of intellect is life), as immaterial, having neither finite nor infinite extension, and consequently no parts, as impassive and unchangeable. To this sublime theology are appended some curious astronomical speculations, apparently intended to reconcile the unity of the Divine Mover with the seeming variety in the celestial motions. To these speculations, which are chiefly derived from previously existing astronomical theories, the philosopher himself does not appear to attach much importance. Resuming the theological argument, he maintains that the Deity, as an ever active and unchanging Intellect, must have an unchanging object of contemplation, and as there is no other such object, he must contemplate himself. The book concludes with a criticism of previous philosophers, whose opinions, as he considers, are irreconcilable with the existence of one supreme Ruler of the Universe.

The two last books must be considered either as an introduction to the eleventh, which most modern commentators regard as the conclusion of the whole treatise, or as a controversial appendix, intended to fortify the positions which that book had established. The controversy is chiefly directed against the Pythagorean and Platonic philosophies, which sought the eternal principle of the universe, the one in the theory of numbers and geometrical magnitudes, the other in that of ideas. The details of this controversy, part of which is little more than a repetition of the arguments of the first book, are chiefly valuable in a historical point of view, as throwing light on the Pythagorean and Platonic doctrines; but they contribute little to the elucidation of Aristotle's own conception of metaphysics.

The Aristotelian first philosophy, as exhibited in the above sketch, has certainly little enough in common with an inductive science of the human mind; and its speculations will probably appear to a modern reader sufficiently vague and

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[1] Κινεῖ δε ὥς ἐρώμενον. *Metaph.* xi. 7.

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barren. But they have a value, historical and philosophical, far beyond their apparent significance to a superficial inspector. They have a historical value, as representing the course of metaphysical inquiry which was pursued, with scarcely an exception, for nearly twenty centuries, and which even now exercises a legitimate influence over the minds of men hardly less extensive than its former absolute dominion. And they have a philosophical value, of which their historical position is the index. However wide may be the gulf that separates the ancient and modern systems of philosophy, they have this at least in common, that both are the produce of human minds, thinking under the same laws, and impelled to speculation by the same irresistible motive of yearnings unsatisfied, and doubts unsolved. Each seeks to comply with the requirements of the same nature; each sets out from the ground of that common consciousness which, in intellect no less than in affection, makes the whole world kin. "Homo sum; humani nihil a me alienum puto," is a maxim no less applicable to the most abstruse speculations of philosophy than to the affairs of our every-day life. Philosophy, in all its aspects, is a contribution to the history of humanity; an attempt, successful or unsuccessful, to carry out the great end and purpose of man's existence. The study of the master-minds of the human race is almost equally instructive in what they achieved and in what they failed to achieve; and speculations which are far from solving the riddle of existence have their use in teaching us why it is insoluble.

Thus it appears that the term METAPHYSICS has been at different times used in two principal senses: 1. As synonymous with Ontology, to denote that branch of philosophy which investigates the nature and properties of *Being* or *Reality*, as distinguished from *Phenomenon* or *Appearance*. 2. As synonymous with Psychology, to denote that branch of philosophy which investigates the *faculties, operations, and laws of the human mind.* These two sciences may be regarded, as has been already observed, as investigations of the same problem from opposite points of view; but this feature of relation has been practically overlooked by the majority of writers on either side; and the link which is to connect the actual contents of each remains still to be pointed out. One, indeed, but hardly definite enough, has been indicated by Dugald Stewart. "On comparing together," says that distinguished philosopher, "the multifarious studies now classed together under the title of Metaphysics, it will be found difficult to trace any common circumstance but this—that they all require the same sort of mental exertion for their prosecution; the exercise, I mean, of that power (called by Locke *reflection*) by which the mind turns its attention inwards upon its own operations, and the subject of its own consciousness." This passage seems to point out a closer connection between the different sense of the term *Metaphysics* than that which it actually expresses. For it refers us not merely to a common method of inquiry, in the process of *reflection*, but also to a common object, in the *facts of our own consciousness.* But to exhibit this connection clearly, the latter term must be extended to a somewhat wider signification than that sanctioned by Stewart's use of it.

On this term, Sir William Hamilton remarks,—"Aristotle, Descartes, Locke, and philosophers in general, have regarded consciousness, not as a particular faculty, but as the universal condition of intelligence. Reid, on the contrary, following probably Hutcheson, and followed by Stewart, Royer-Collard, and others, has classed consciousness as a co-ordinate faculty with the other intellectual powers, distinguished from them, not as the species from the individual, but as the individual from the individual. And as the particular faculties have each their peculiar object, so the peculiar object of consciousness is *the operations of the other faculties themselves, to the exclusion of the objects* about which those operations are conversant.

"This analysis we regard as false. For it is impossible, in the *first* place, to discriminate consciousness from all the other cognitive faculties, or to discriminate any one of these from consciousness; and, in the *second*, to conceive a faculty cognisant of the various mental operations, without being also cognisant of their several objects.

"*We know;* and *we know that we know:*—these propositions, *logically* distinct, are *really* identical; each implies the other. We *know* (*i.e.*, feel, perceive, imagine, remember, &c.) only as we *know that we thus know;* and we *know that we know*, only as we know in *some particular manner* (*i.e.*, *feel*, *perceive*, &c.). So true is the scholastic brocard:—'*Non sentimus nisi sentiamus nos sentire; non sentimus nos sentire nisi sentiamus.*' The attempt to analyse the cognition *I know*, and the cognition *I know that I know*, into the separate energies of distinct faculties, is therefore vain.

"But the vice of Reid's analysis is further manifested in his arbitrary limitation of the sphere of consciousness; proposing to it the various intellectual operations, but excluding their objects. . . . The assertion that we can be conscious of an act of knowledge, without being conscious of its object, is virtually suicidal. A mental operation is only what it is, by relation to its object; the object at once determining its existence, and specifying the character of its existence. But if a relation cannot be comprehended in one of its terms, so we cannot be conscious of an operation without being conscious of the object to which it exists only as correlative. For example, We are conscious of a perception, says Reid, but are not conscious of its object. Yet how can we be conscious of a *perception*, that is, how can we *know* that a perception exists,—that it is a perception, and not another mental state,—and that it is the perception of a rose, and of nothing but a rose,—unless this *consciousness* involve a knowledge (or consciousness) of the object, which at once determines the existence of the act, specifies its kind, and distinguishes its individuality? Annihilate the object, you annihilate the operation; annihilate the consciousness of the object, you annihilate the consciousness of the operation." [1]

Extending the term *facts of consciousness*, in accordance with the principle of the above criticism, to denote all those phenomena of mind whose existence in a definite form, as operations of a particular kind, and the knowledge of that existence, are identical; we may find in these facts an adequate object for the investigations of *Metaphysics*, in the most general sense of the term; and in this sense, accordingly, we would define the science of which we are treating, as "Metaphysics, or the philosophy of the facts of consciousness, considered subjectively, in relation to the mind knowing, and objectively, in relation to the things known." Metaphysics will thus naturally divide itself into two branches,—PSYCHOLOGY, or the science of the facts of consciousness as such; and ONTOLOGY, or the science of the same facts considered in their relation to realities existing without the mind.

Neither of these two branches of metaphysics, thus treated, can be considered as exhausting the senses in which their respective names have been used. Psychology, both in its earliest and in some of its latest developments, has been treated in connection with physiology, and thus extended to phenomena beyond the range of the facts of consciousness properly so called. Aristotle, the first systematic expositor of the science, enumerates, in conjunction with the threefold division of the facts of consciousness into those of sensation, thought, and volition,[1] a fourth function of nutriment and growth, the existence of which cannot be identified with the consciousness of it. *I perceive*, and *I know that I perceive; I think*, and *I know that I think; I will*, and *I know that I will*:—these propositions are severally equivalent to each other; but not so *I digest*, and *I know that I digest.* Modern writers on psychology have treated it with a similar extension to physiological phenomena. Ontology, in like manner, has, in modern times especially, sought a foundation for its speculations beyond the domain of consciousness, and even contradictory to it; nearly the whole of the systems of German metaphysicians since Kant being a series of attempts, more or less plausible, to account for the origin of the facts of consciousness themselves, by postulating a principle of which we are not and cannot be conscious. Neither of these extensions of the field of inquiry will be adopted in the present article. We shall, indeed, have to borrow largely from physiology in illustration of the bodily conditions on which mental consciousness depends; but the two sciences will be considered as distinct branches of inquiry, though the conclusions of the one may throw some collateral light on the researches of the other.[2] On the other hand, the transcendental method, which seeks to found a philosophy of being in a point above consciousness, will be rejected, from a conviction of its utter inability to furnish any reliable or even intelligible results. All such theories are open to two fundamental objections: they cannot be communicated, and they cannot be verified. They cannot be communicated; for the communication must be made by words, and the meaning of those words must be understood, and the understanding is a form of consciousness and subject to the laws of consciousness. They cannot be verified; for, to verify, we must compare the author's experience with our own; and such comparison is again an act of consciousness, and subject to its laws. This consideration must serve as our apology for the neglect of systems which are indeed entitled by their celebrity to a prominent place in the history of metaphysical philosophy, but which cannot, except upon the ground of their truth, claim admission into a treatise on the science itself.

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[1] *Discussions*, p. 47.

There is a wide application of the term *consciousness*, in which it is coextensive with the whole cycle of human knowledge; for we can know nothing without being conscious that we know it; and we can investigate no objects but those whose existence, real or apparent, must be made known to us by consciousness. In this sense, what is out of consciousness is out of the field of human knowledge altogether. But this consideration does not affect the definition which assigns the facts of consciousness as the proper object of metaphysical science. For in other sciences those facts are considered, necessarily indeed, but secondarily only, as the means by which the direct objects of such sciences are made known to us. The manner in which consciousness operates as the instrument of the physical sciences is not taken into account by those sciences, nor is the nature and veracity of its testimony called in question. Physical science does not trouble itself with the inquiry, whether the objects which it investigates are real or apparent; qualities of matter or modes of the spectator's own mind; whether they are gained directly or indirectly; by innate or acquired powers; by one faculty of the mind alone or by the union of many. Its researches are not in any way affected by the adoption of this or that theory of consciousness itself; though consciousness is the means by which its objects are conveyed to it. In metaphysical science, on the other hand, consciousness itself is the direct object of our inquiries; and that in two points of view: 1. In its *phenomenal character*, in relation to the conscious subject; in which we consider the several affections of the human mind in which consciousness consists, and the faculties, operations, and laws, upon which those affections depend. 2. In its *real character*, in relation to the objects of which we are conscious; in which we consider the veracity of its testimony in reference to things without the mind, and the indications which it is supposed to furnish of the actual constitution of those things. Of these two inquiries, the first is preliminary and auxiliary to the second; both because it is necessary to know what the facts of consciousness are in themselves, before inquiring into their ulterior relations, and because the light which the former inquiry is calculated to throw on the laws and limits of human thought, will be of importance in determining how far it is possible to obtain a satisfactory answer to the latter. We commence, then, with the first portion of our inquiry.

I.—PSYCHOLOGY, OR THE PHILOSOPHY OF THE PHENOMENA OF CONSCIOUSNESS.

Consciousness, in its relation to the subject or person conscious, is of two kinds; or rather, is composed of two elements—the presentative or intuitive, and the representative or reflective. The phenomena of the former class may be distinguished by the general name of *intuitions;* those of the latter by that of *thoughts.*

Presentative or intuitive consciousness is the consciousness of an *individual object*, be it thing, act, or state of mind, immediately present before me, *here* or *now;* that is to say, with a definite position in space or in time, or in both. Representative or reflective consciousness is the consciousness, *primarily* and *directly*, of a *general notion or concept*, indifferently related to any number of possible individuals; *secondarily* and *indirectly*, of *one or more actual individuals*, conceived as exhibiting at the moment, in an unity of representation, the several attributes which the general notion involves. For example, I see a triangle drawn on paper. I need not know that the figure now lying before me is called a triangle. I may be unable to give any definition of it. It is enough that I see a figure, which I did not construct for myself according to any pre-existing notion, but found there already constructed. This is *presentative consciousness*, or *intuition*. The triangle is before me, as an object seen in itself, not necessarily representative of anything else. But, having seen the triangle, I gather a general notion of its figure, indifferently applicable to it or to any other specimen; and I imagine a particular figure, at another time and in another place, as embodying that notion. This is *representative consciousness*, and in a two-fold manner. First, the general notion is representative of any number of possible triangles, even when none is actually present to the consciousness. Secondly, the same notion is now actually exhibited in an image; which image represents the original figure from which the notion was derived. The same distinction is applicable to mental as well as to bodily phenomena. I feel an emotion of anger; I am conscious of its presence now, as a definite state of mind distinguishable from others. This consciousness is *presentative.* When the angry fit is over, I meditate upon my past state, and recal in imagination the emotion which I have experienced. This consciousness is *representative.* Presentative consciousness contains two constituent elements—the conscious subject, and the object of which that subject is conscious. Representative consciousness contains three elements—the subject, the object (*i.e.*, the image), and the concept or general notion mediating between them. A fourth element is implied as a condition, though not actually present in consciousness, viz., the original intuition from which the notion was derived, and which the object or image represents.

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[1] I have ventured to use the term *volition*, as nearly equivalent to the *motive principle* of Aristotle; though the connection of the latter with the will is but imperfectly exhibited in his treatise, owing to the want of a strict distinction between the phenomena of human consciousness and those of animal life.

[2] The limits of psychology and physiology are defined in an excellent essay by M. Jouffroy, *Nouveaux Mélanges Philosophiques*, p. 222. The phenomena of consciousness, which are known only as affections of myself, belong to the former science; those of animal life, which can be discerned by observation of foreign bodies, belong to the latter.

The ultimate object of all consciousness is thus an *individual;* for all intuitions are directly cognisant of individuals, and all concepts, to be realized in consciousness, require to be individualized in an image. Without the application of this test, we should not be able to distinguish between the conceivable and the inconceivable; between signs indicative of notions and signs indicative of no notions at all. I may define a *triangle* as a rectilinear figure of *three* sides; and I may also define a *biangle* as a rectilinear figure of *two* sides; and nothing but the attempt to construct the corresponding images can show me that the one term denotes a conceivable object, and that the other is an inconceivable piece of nonsense. The individual is thus the ultimate object of all actual consciousness; in intuition directly, and in thought indirectly. To complete our explanation, we must therefore determine what is meant by an *individual.*

By the term *an individual,* is meant, in psychology, no more than an object occupying a definite position in space or time. It is indifferent, in this point of view, whether the several individuals thus distinguished can or cannot really exist apart from each other; or whether the portion of space or time which each occupies is distinguished from other portions naturally or arbitrarily. The leaf which I see before me is an individual; so is the bough; so is the tree; so is the forest. Each has its own position in space, which nothing else can occupy along with it. A chain of six feet long is an individual; whether it exist separately, or only as part of a longer chain. Every link, and every fragment of a link, of the chain is again an individual, in so far as, with or without physical separation, it may be made a distinct object of sight or thought. What space is to material individuals, time is to individual phenomena of mind. I may feel anger or fear many times in succession; but each has its own peculiar portion of time; and the passion which I felt yesterday, however similar in other respects, is numerically distinct, as an individual state of mind, from that which I felt the day before yesterday, or that which I am feeling at this moment. We need not at present inquire whether each of these distinct individuals has in reality a separate existence apart from our point of view or not. They may be independent units: they may be fractions of larger units: they may be multiples of smaller units: they may be constituent parts of one only real unit, the universe. They may be modes of my own mind, or they may be attributes of something distinct from myself. These questions belong to ontology, not to psychology. It is sufficient for our present purpose to state, that whatever occupies a distinct portion of space, however arbitrarily distinguished, is an individual object of external intuition; and whatever occupies a distinct moment of time, without extension in space, is an individual object of internal intuition.

On the other hand, general notions or concepts, as such, have no definite position in time or space; though, when realized in an individual act of thought, they *must* have a relation to the former, and *may* have to the latter. The definition of a triangle, as a rectilinear figure of three sides, is indifferently applicable to a triangle in England or to one in America; to one drawn on paper or to one engraved on stone; to one conceived yesterday or to-day. But when actually employed in conception, it becomes *my present thought about a triangle;* and this has its definite position in time, and is related to an image conceived as occupying a definite position in space. The verbal description of a particular coin is indifferently representative of all coins struck from the same die; but two shillings of the same coinage, though they may be undistinguishable in other respects, are yet separate individuals, as occupying distinct portions of space. The general notion is thus *potentially* representative of many individuals; that is to say, it may, *in different acts of thought,* be employed in relation to any member of a certain class; but when *actually* so employed, *in any one single act of thought,* it becomes amalgamated with the individual in which its attributes are united, and is only conceived along with the special characteristics of the individual. Thus the notion of a triangle, as such, does not imply that it is equilateral, isosceles, or scalene; but I can never actually conceive a triangle which is none of these, or all of them at once. I must conceive it as some one of them only. But, *in successive acts of thought,* the same general notion may be represented in the imagination, at one time with three equal sides, at another with two, at another with all unequal. The notion is thus not the adequate and actual representative of any single object, but an inadequate and potential representative of many.

We have thus one characteristic of the concept or general representative notion; namely, *that it cannot in itself be depicted to sense or imagination;* though, in every complete act of representation, it forms one element of an image which is so depicted. The mere notion of a triangle, apart from the consideration of the equality or inequality of its sides, is not an object of imagination; nor the notion of an equilateral triangle, without a given length of the sides; nor, again, the notion of an equilateral triangle whose sides are each two feet long, without the additional limitation of its occupying a particular position in space;—under which limitation, it is no longer general, but individual, and can be constructed in the imagination as an object of intuition. A second characteristic of all general notions is, *that they require to be fixed in a representative sign.* The general notion, as such, is not a sensible image, but an intelligible relation; and such a relation, as far as our experience can testify, cannot be apprehended without the aid of *language,* *i.e.*, of some system of signs, verbal or other. The case of the deaf and dumb is no exception to this rule; for *language,* in the above sense, is not synonymous with *articulation.* The mental development of the deaf and dumb is effected by the substitution of a system of signs addressed to the eye or the hand, in the place of one addressed to the ear; and this system performs precisely the same office in relation to them that speech performs in relation to others: it constitutes, in fact, *their language.* Language in this sense appears, as far as experience can inform us, to be necessary, not merely to the communication, but even to the formation of thought. The notion, as such, must be emancipated from all special relation to space or time. The definition of a triangle must not imply where it exists; nor the definition of anger, when it takes place; and this emancipation is never completely effected, except by means of symbols, verbal or other, by which the notion is fixed as a relation in the understanding.[1] We have thus, in the complete exercise of thought, three successive representations. The sign is representative of the notion; the notion is representative of the image; and the image is representative of the object from which the notion was formed.

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[1] The distinction between intuition and thought thus corresponds to that noted by Leibnitz between *intuitive* and *symbolical* knowledge. See his *Meditationes de Cognitione Veritate et Ideis,* where, however, the distinction is hardly marked with sufficient precision.

Presentative and representative consciousness, thus distinguished, must be considered, in their actual exercise, as indicating a logical rather than a real division; as pointing out the elements of a perfect act of consciousness, which are separable in thought, rather than two distinct acts existing separately in practice. In every complete act of consciousness offered to us for analysis, the presentative and representative elements are combined; and without such a combination, it would appear as if consciousness, properly so called, could have no existence. To have a complete consciousness, for example, of any particular object of sense, say of an oak tree, two conditions are necessary: first, that certain impressions should be made upon the organ of sensation; and, secondly, that these impressions should be discerned as constituting an object; *i.e.*, that they should be separated from all other objects, and considered by themselves as constituting a whole, which can be compared with and distinguished from other wholes. To the mere sight the oak is presented along with the surrounding scenery; but to recognise it as an oak, the trunk must be considered separately from the ground from which it springs, and the branches and the leaves must be discerned as parts of the tree, and separated from the surrounding objects. The reception of the whole scene presented to the eye is an act of mere intuition; but the knowledge of each impression as being what it is, and the combination of a portion of such impressions into a separate whole, is an act of reflection or thought.[1] Neither of these two elements alone can constitute a complete act of consciousness. Let us suppose, for instance, the existence of a being furnished with human organs of sensation, but with no power of remembering or reflecting upon the objects presented to them, and no continuance of any impression beyond the moment of its actual presence. It is probable that, in such a case, though diverse objects might be successively presented to the senses, yet there would be no consciousness of their diversity; for such consciousness requires the juxtaposition of the objects in the mind, and this can only be effected by memory. Animals, trees, and stones, might be successively placed before his eyes. Pleasure and pain and fear and anger might possibly take place within him; but as each departed, he would have no knowledge that it had ever existed, and consequently no power of comparison with anything else. He would thus have no distinct consciousness of each object *as referred to a separate notion:* he could not say, this which I see is a tree or a stone; this which I feel is fear or anger. His consciousness, if consciousness it could be called, would probably be no more than an indefinite sense of uneasiness, a feeling of momentary irritation in the organ affected, but without discerning in what manner it is affected, and without distinguishing the permanent self from its momentary affection.[2] This is the lowest degree of intelligence, the germ of consciousness, but not itself entitled to the name; as being deficient in the essential conditions of limitation and difference, having not realized the distinction between subject and object, or between one object and another.[3] But let us go one step further, and suppose the same being to be capable, not merely of receiving, but of retaining and associating together, various impressions, though still destitute of the power of reflecting upon them. Let us suppose; that is to say, that the impression, once made, may continue for a time in conjunction with others, and spontaneously recur upon certain occasions; though the subject of the impression is unable to set it apart as an object of thought, or to recal it by an effort of his own will. We have now a second stage of intelligence—a partial consciousness, embracing a variety of objects and relations of similarity or dissimilarity between them; we have the recurrence, moreover, of certain feelings upon the repetition of the circumstances under which they were originally excited. In a word, we have *an association of intuitions.* But the conditions of consciousness are not yet complete; for memory, at this stage of its development (the μνήμη of Aristotle), though it implies a repetition of phenomena, does not as yet imply a knowledge that it is a repetition. An animal at this stage of intelligence might, for instance, be beaten for a fault, and the recurrence of the fault might naturally suggest an imagination of the pain; but this imagination need not be consciously regarded as a remembrance of pain felt at a former time. The reproduction would be spontaneous, not voluntary, and probably not accompanied by any conscious reference to past time. Let us now assume another step in the scale of intelligence, and suppose our imaginary being to possess, not merely a power of receiving and retaining impressions, but also of recalling them by a voluntary effort (the ἀνάμνησις of Aristotle). This implies that the leading features of the impression remain fixed in the mind, independently of the presence of the object at a particular place or time. This is the distinctive feature of the concept or general notion, in which, whether by a conscious process or not, the mind abstracts the leading attributes of an object from the condition of limitation in space and time, and is able, under the guidance of those attributes, to recognise the object when presented to it at other times, and, under the same guidance, to reproduce at will the image of the object when absent. Here we have the cooperation of thought proper, as evidenced by a conscious recognition of objects as such, and of their several relations to the one conscious self, whose permanence and personal identity is necessarily discerned in every act of consciousness properly so called, as the continuous subject of successive modifications. This is the only form of intelligence which can properly be expressed by the judgment, *I know*, or *I know that I know;* and at this stage we have reached the point of true consciousness, in which the existence of a phenomenon is identical with the knowledge of its existence, and the mind, in the act of being affected in any manner, is at the same time cognisant of being so affected.

The above stages must not be regarded as corresponding to a chronological development of the actual phenomena of the human mind. Logically, perhaps, the several elements by whose co-operation consciousness is produced, may be thus analysed; but in the actual progress of the mind by education, the several elements are so mingled together, that it is impossible to point out any particular time at which one exists separately from the rest, or to mark the period of each new accession. Classifications, which we are unable to form for ourselves, are, from the earliest dawn of intelligence, given to us, already formed by others. The child, in learning to give names to the objects placed before him, and to repeat those names at each recurrence of the objects, learns, unconsciously to himself, to perform the acts of reminiscence and generalization, along with that of sensation, and advances by imperceptible degrees to a definite consciousness. To point out each successive stage of the process by which sensibility gives birth to intuition, and intuition to thought, is as impossible as to determine the several moments at which the same child receives each successive increase of his stature, or each successive development of his bodily powers. The mind, like the body, acquires its functions by insensible degrees, "unseen, yet crescive in its faculty;" and we find ourselves in the possession and exercise of nature's gifts, without being able to say how we acquired them.

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[1] Cheselden says of his patient, who had been couched for cataract,—"He knew not the shape of anything, nor any one thing from another, however different in shape or magnitude." The language is ambiguous; it may mean that he was unable at first to separate the different objects in the field of vision from each other, or it may mean only that he could not distinguish them by their right names. Condillac goes beyond the warrant of the original in rendering "Il apercevoit tous les objets pêle-mêle et dans la plus grande confusion." (*Traité des Sensations*, p. iii., ch. 5.) But Cheselden's experiment, besides the want of precision in the report, is not decisive for other reasons: 1. Because a cataract does not produce total blindness; 2. Because the other senses had been educated before the operation was performed.

[2] A state of representation very nearly resembling this is supposed by Leibnitz to exist in his monads. This state he calls perception without apperception or consciousness, and considers it as the characteristic state of existence of simple monads, as distinguished from souls, which are capable of memory and distinct consciousness. (See *Monadologie*, sect. 14, 19.)

[3] If the testimony of psychology is to be trusted, the sublime intellectual condition in which subject and object are identified, a condition longed for by mystics of all ages, and proclaimed as the basis of philosophy by modern German metaphysicians, is a degradation of man to the level, possibly, of a zoophyte. Yet there have not been wanting philosophers to proclaim this lowest possible manifestation of animal existence as the exaltation of man to the level of God—as the state of Deity contemplating itself.

Consciousness proper, as above described, must possess in some degree the attributes of *clearness* and *distinctness*. Using the same term in a wider and less accurate sense, we may distinguish between an *obscure* or an *indistinct*, and a *clear* or a *distinct* consciousness. An act of consciousness, whether presentative or representative, is *clear* when its object as a whole can be distinguished from any other; when this cannot be done, it is *obscure*. An act of consciousness is *distinct* when the several parts constituting its object can be distinguished from each other; when this is not the case, it is *indistinct*.[1] To form a clear or distinct consciousness, an act of reflection must accompany the intuition. An obscure or indistinct consciousness may in some degree be obtained by intuition alone. The latter contains all the materials of the former, though not disposed in the same relations to each other. In an obscure or indistinct intuition, we may be dimly aware of the existence of differences of some kind, but be unable to say what they are. In order to obtain this latter knowledge, the first step must be to separate our confused intuition into distinct portions; and in performing this task, we are, as a matter of fact, invariably assisted by the distinctions of language; that is to say, by a classification already performed by the reflection of others. By learning to recognise under their names the different portions of a confused intuition, we take the first step towards a clear and distinct consciousness of things and thoughts. It is obvious, however, from what has been said before, that the terms *clear* and *distinct* are rather relative than absolute, and that a perfectly obscure consciousness is no consciousness at all in the proper sense of the term.

What has been said concerning the relation of thought to language may perhaps suggest two other questions, which have often been discussed without any satisfactory answer. It may be asked, in the first place, how we are to account for the origin of language itself, and how the distinctions which language now helps us to make could themselves have been made available in the original imposition of names; and, in the second place, it may be asked how the different phenomena of consciousness can be distinguished from each other by the lower animals, who have no nomenclature to assist them. Both these questions admit of many ingenious conjectures, but of no scientific answer. And the reason is obvious; for both relate to states of consciousness which we never have experienced and never can, and which are so utterly unlike our own, that we have no reliable data for examining them. To conceive an inventor of language, we must conceive a man existing in the full maturity of his faculties; those faculties not having been developed by any of the means that are indispensable now, and consequently not having assumed the same form in their development. Such a being is to us as inconceivable as one of a wholly different mental constitution. His thoughts are not our thoughts; his conditions of speech are not ours. Our experience is so unlike what his must have been, that it will but mislead us if we reason from it; and if we conjecture without the aid of experience, we deal in fiction, not in philosophy. Nor is the difficulty lessened if we suppose language to have been of Divine origin; for the real problem is, not to determine how the system of signs came into being, but how man learned to associate it with his own distinctions of thought; or how, independently of it, he came to have such distinctions at all. The origin of language must ever remain a mystery; but it is a mystery which has its parallel in every other phenomenon of the sensible or intelligible world; for of all, while the existence is undeniable, the generation is inconceivable. That a man living in solitude from his earliest infancy, supposing him to be preserved to animal maturity, or any number of such men brought together into a separate society, apart from other men, could never acquire the mental power to invent a language, seems as nearly certain as such a point can be. Beyond this we have no means of speculating on the origin of language at all. Nor are we much better off in relation to the second question, as to the mental condition of the lower animals. To analyse a dog's consciousness, it is necessary that we should have a dog's consciousness ourselves; and besides this, that we should retain a distinct recollection of it after we have acquired a human one. The dog can distinguish his master from a stranger; that is clear. He can be educated by associations of pain or pleasure; that is clear also. But when conscious of his master's presence, does he recognise him as a being distinct from all other objects—as an object that can be observed or contemplated alone? When he is uneasy at losing him, has he a distinct consciousness of what it is that he wants? When he is educated, does he consciously represent to himself the association between tit-bits and sitting upright? And if he does so, does he do it by the aid of any system of representative signs, which, though unintelligible to us, performs an office analogous to that of human language?[2] In a word, does his state of intelligence more nearly resemble the second or the third stage of our supposed development of consciousness? Instinct resembles reason in many of its results; does it therefore resemble it in its manner of obtaining them? We may speak positively on these points with all the hardihood of ignorance; but in doing so, we are speculating on the nature of an intelligence different from our own, and whose conditions cannot even be conjectured, except by the arbitrary assumption of its partial similarity to our own.

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[1] The difference between *clear* and *obscure, distinct* and *indistinct* or *confused* cognitions, is due to Leibnitz. (See his *Meditationes de Cognitione Veritate et Ideis.*)

[2] Mr Morell states positively the view which we have only ventured to hint interrogatively. "While the brute perceives objects, and acts in reference to them only *instinctively*, either for the satisfaction of its appetites, or for self-preservation; a conscious separation is instantly effected by the *human* faculty between the subject and the object. In this separation lies the first distinctive act of *human intelligence*, an act to which there soon succeeds an apprehension of *qualities* in the external object, totally different from any intelligence that can take place in the case of the lower animals. The animal does not think within itself, I am a dog, or a horse, and that is a hare, or a corn-field; it is simply impelled *by the force of instinct* towards the object, without any apprehension of its own personality, as distinct from the thing presented to it. On the other hand, the child or the savage, without the least culture whatever, *consciously* separates self from the objective world in the very first distinct act of *perception*; and it is exactly here, in this very act, that the *intellectual* quality of perception is first manifested." (*Elements of Psychology*, p. 141.)

Human consciousness, then, in the only form in which it can be examined and described, is a compound of various elements, of whose separate action, if it ever existed, we retain no remembrance, and therefore no power of reproducing in thought. It is impossible to have a distinct conception of an act of pure sensation, *i.e.*, of an affection of the organs of sense only, unaccompanied by reflection upon it; for such an affection, though possibly the earliest step in our mental development, could not at that time be recognised as such, nor leave traces that could be recognised afterwards. Our personal consciousness, like the air we breathe, comes to us as a compound; and we can no more be conscious of the actual presence of its several elements than we can inhale an atmosphere of pure azote. Hence it follows, that in distinguishing and describing the several phenomena of consciousness, we must describe them according to their *predominant characteristics as compounds*, not according to their *separate natures as simples*. The phenomena, for example, of sensation, are so called from their prominent feature; the presence, that is to say, of an object affecting in a certain way the organs of sense; though the consciousness of the manner of that affection in each case, and consequently its existence as a distinct phenomenon, depend likewise upon the co-operation of other faculties, which play a necessary though a subordinate part. The neglect of this consideration constitutes the weak point in Condillac's celebrated hypothesis of the statue becoming conscious. He starts with the assumption that the possession of a single organ of sense is sufficient for the discernment of distinct sensations as such, for remembrance and comparison of various sensations, for the preference of one to another, for voluntary efforts to recal them, and for self-consciousness throughout. Whereas, in truth, though the existence of the sensation in a perfect state is identical with the consciousness of that existence, yet we are by no means warranted in assuming that either can be brought into that state by the operation of an isolated organ of sense. With this preliminary caution as to the relation of the several faculties and acts of consciousness to each other—a caution which must be carefully borne in mind throughout—we shall now proceed to examine and describe the various phenomena of consciousness separately, so far, at least, as separation in this case is possible.

OF PRESENTATIVE OR INTUITIVE CONSCIOUSNESS.

The distinctive feature of presentative consciousness consists in the fact, that it is caused by the actual presence of an individual object, whether thing, act, or state of mind, occupying a definite position in time, or in space, or in both. It is true that this object is not discerned as such, and the consciousness of it, therefore, is not fully realized without the co-operation of the representative faculties; and it is true also that representative consciousness, when complete, is exhibited in an individual unity of representation; but as the presence of the individual object is in the one case the principal, in the other only an accessory feature; and as in the one it may be regarded as the cause, in the other as the effect of the accompanying representation, it furnishes a sufficient principle of distinction between the two. We shall therefore class under the general denomination of *Intuitions*, all those states of consciousness in which the actual presence of an object, within or without the mind, is the primary fact which leads to its recognition as such by the subject; and from these will be distinguished, under the name of *Thoughts*, all those states of consciousness in which the presence of the object is the result of a representative act on the part of the subject. In the former case, the presence of the object is involuntary; in the latter it is voluntary. In both the presentative and representative faculties act in combination, for this is the condition of all complete consciousness; but in the former case the object is *given to*, in the latter it is *given by*, the conscious act. For example, while I am in the company of a friend, I have by sight an intuitive consciousness of his presence. I do not cause his presence by any mental effort of my own: it is *given to* me; and so long as my eye is turned towards him, I cannot help seeing him. But if I am thinking of an absent person, and endeavour to recal to mind his features, I make a voluntary effort, and thereby bring into consciousness a mental image which becomes internally now present; but the presentation is one of my own making, constructed by means of the reflective or representative faculty. In adopting the term *presentation* or *intuition*, to express the consciousness of any individual affection of the mind, a writer may be liable to the charge of innovation, in what was at least in the last generation the established language of English philosophy. But in this case necessity has no law. We need a term which shall indifferently express the presence of an individual sight or sound in the eye or ear, and of an individual emotion or volition in the mind; and if none such exists in current use, there is no resource but to coin one. It may be added, that if such a term had been in use in the days of Locke, his writings need not have been liable to the perpetual misunderstanding which arises from his ambiguous use of the term *reflection*. The same apology must serve for the occasional introduction of other philosophical terms, which, though gradually coming into use, are hardly as yet in general circulation.

Presentative consciousness, thus distinguished, appears, like all consciousness, in the form of a relation between the subject or person conscious, and the object, or that of which he is conscious. These two terms are correlative to each other, and imply each other. The subject is a subject to the object, and the object is an object to the subject.[1] The subject can only be conscious by knowing itself to be affected in a particular manner by an object; the object can only be known as affecting the subject in a particular manner. Thus the two are given in relation as mutually determining and determined by each other. We are affected in various manners by various objects presented to us. But these objects again exist for us as objects, only in so far as they are discerned by our faculties of consciousness. The subject and the object are thus only cognisable as existing in and affected by their mutual relation. We cannot be conscious of a pure *ego*, or subject affected in no particular manner; nor yet of a pure *non ego*, or object out of relation to our own cognitive powers. Hence arises a distinction between *phenomena*, or things in consciousness, and *things in themselves*, or things out of consciousness. We know the object only as it stands in relation to our faculties, and is modified by them. We are not sure that, if our faculties were altered, the same things would appear to us in the same form as they do now: we are not sure that they do appear in the same form to all existing intelligent beings; for we know not how far the faculties of other beings resemble our own. But, on the other hand, we have no right to dogmatize on the negative side, and to assume, with equal absence of ground, that things *are not* in themselves as they appear to us. This question, however, belongs to ontology, and will be examined in its proper place. Psychology is concerned with *the phenomena of consciousness as such.* It has nothing to do with the ulterior realities whose existence and nature consciousness perhaps indicates, but certainly does not ascertain.

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[1] A word in passing on the often used and often misused terms *subjective* and *objective*. All consciousness has a subject and an object; but sometimes the object determines the character of the subject, and sometimes the subject determines the character of the object. In the former case the product is objective, in the latter it is subjective. Thus, a nervous affection dependent on the constitution of my animated organism is subjective; a quality perceived or conceived as existing in the constitution of the object is objective: a code of morality which allows each man to fix his own standard of right and wrong, is subjective; one which requires the opinions of men to conform to a rule independent of themselves, is objective. This explanation, however, applies only to the modern signification of the terms.

Nevertheless, though consciousness exists, and can be conceived to exist, only in the psychological relation of a subject to an object, it is possible in some degree to distinguish between the elements apparently due to each. Not that these can be directly discerned apart from each other; but that in their combination each exhibits certain features which appear to indicate a subjective or an objective origin. If there are in every act of consciousness certain invariable elements, which no change of consciousness can ever obliterate or alter, which no effort of thought can get rid of or conceive as absent, and without which consciousness itself cannot be imagined as possible,—these may be conjectured to owe their existence to the constitution of the subject, which remains one and unchanged in successive acts; while the changeable features which distinguish one mode of consciousness from another, are probably due to the different constitutions of the several things of which the subject is successively conscious.[1] The former may therefore be distinguished as constituting the *form* or subjective ingredient of consciousness; the latter as constituting the *matter* or objective ingredient.

OF THE FORM OF CONSCIOUSNESS IN GENERAL.

The analogy which gives rise to the terms *form* and *matter*, as used to denote the subjective and objective elements of consciousness, is obvious. In a work of art, the *form* is that which is given *by* the artist; the *matter* is that which is given *to* him. The sculptor, for instance, receives the unshaped block of marble, and imparts to it the form of the statue. The conscious mind, in like manner, receives its materials from without, and imparts to them a form by its own act, according to its own laws. The form of consciousness in general consists in *relation to a subject.* Whatever variety of materials, whether for intuition or thought, may exist within reach of my mind, I can become conscious of them only by recognising them as *mine.* By this the several materials are in each case set apart or united, and known as *an object*, of which *I am conscious;* and without such knowledge no act of consciousness is possible. Relation to the conscious self is thus the permanent and universal feature which every state of consciousness, as such, must exhibit; while in every other respect the several states may differ from each other, being distinguished as sensations, volitions, thoughts, &c.; or more particularly, as states of sight or hearing, as virtuous or vicious acts, as conceptions or judgments; or more minutely still, as the sight of a tree or the hearing of music, as an act of benevolence or ingratitude, as the conception of a triangle or the judgment that the angles of a triangle are equal to two right angles. But in all alike there is a necessary relation to one and the same conscious self; the sight is *my* sight, the act is *my* act, the thought is *my* thought. If we further examine the manner in which this universal relation manifests itself in the particular case of presentative consciousness, we shall find two special forms or conditions common to all possible states of external or internal intuition respectively—namely, SPACE and TIME.

OF THE FORMS OF INTUITIVE CONSCIOUSNESS—SPACE AND TIME.

Space is the form or mental condition of our perception of external objects. The phenomena of the material world may vary in an infinite number of ways; but, under every variety, they retain the condition of existing in space, either as being themselves sensibly extended, or as having a local position in the sensitive organism. Without this condition, their existence at all as phenomena is inconceivable. We may suppose the phenomena changed as we will in other respects, but we cannot suppose them to exist out of space. We may suppose any given phenomenon to be non-existent, but the non-existence of space is beyond our power of supposition. Hence space is necessarily regarded as infinite (though not positively conceived as such), for to suppose it finite is to suppose a point at which it ceases to exist. It has thus the characteristics of universality and necessity which appear to mark it out as an *à priori* law or condition of the conscious mind, not as the adventitious result of any special experience. And this conclusion is confirmed by other considerations. For the consciousness of space, though accompanying the perceptions of various senses, cannot be regarded as properly the object of any one of them. There is a visible extension, or apprehension, of space as occupied by light and colour; there is a tangible extension, or consciousness of certain portions of the organism as occupied by tactual impressions; and there is probably a certain consciousness of locality in the exercise of the other senses. But pure space is not identical with any of these; for the blind man may form as positive a notion of it as the seeing man, and one debarred from the sensation accompanying the act of touch would not thereby lose all consciousness of space; and the same argument applies still more clearly to the other senses. Again, the exercise of the locomotive faculty implies a consciousness of space as containing our own body; but the idea of space cannot be said to be derived from locomotion, since the mere volition to move implies a prior consciousness of this relation. Space is thus not by itself an object of sensible intuition, but forms one element of all such objects, being presented in the form of a relation between parts out of each other, and hence being distinctly conceivable only in conjunction with the things related. Pure space has thus one character in common with concepts or general notions, namely, that it cannot by itself be depicted to sense or imagination; but in all other respects it is essentially different from them. A concept is logically as well as chronologically posterior to the individuals which it represents. It implies a prior perception of them, and it has no objective existence but in them. Space is logically, and in some degree chronologically, prior to the objects of sense. It is the condition of their existence as objects, and is itself necessarily conceived as existing independently of any *given* contents.[1] A concept is indifferently representative of many objects. Space is presented to consciousness as one only (for the division of space is purely arbitrary), and thus is not conceived as comprehending individual objects under it, but as containing them in it. Space is thus an element of the sensitive consciousness, presented in itself, not derived from or representative of anything else; and, though always manifested on the occasion of some special experience, it cannot be regarded as the product of experience, nor its notion be constructed from empirical data. It cannot properly be described as an *innate idea*, for no idea is wholly innate; but it is the innate element of the ideas of sense which experience calls into actual consciousness. To describe experience as the cause of the idea of space, would be as inaccurate as to speak of the soil in which it is planted as the cause of the oak; though the planting is the condition which brings into manifestation the latent powers of the acorn. To maintain that the mind contributes nothing to the formation of consciousness, because experience contributes something, is as unreasonable as to assert that the acorn may indifferently become an oak, or an ash, or an elm, according to the soil in which it is planted. Yet such reasoning has often been used to prove that the mind is but the passive recipient of impressions from without.

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[1] An apparently opposite use of this criterion is made in some of the current theories of philosophy. Thus, in the distinction, which we shall shortly have to notice, between the primary and secondary qualities of body, those attributes of which the cognition is common to the several senses are usually regarded as existing in the bodies themselves; while those which are peculiar to this or that act of sensation are considered as affections of the sentient subject. But in truth the opposition is rather apparent than real. For the secondary qualities, as they are commonly distinguished, depend for their cognition, not on the constitution of the pure mind or subject proper of consciousness, but on that of the nervous organism as animated; and this latter, though in particular acts of sensation it is regarded as pertaining to the subject, yet, in reference to consciousness in general, and to the personal self properly so called, must be regarded as belonging to the object, and, as such, is present or absent in different acts of consciousness. Indeed, the above distinction between form and matter, though not thoroughly carried out in reference to the sensibility till the time of Kant, had, in relation to thought, been long previously an established canon in logic.

In the actual development of human consciousness, the condition of space accompanies every complete exercise of the bodily senses; for in all there is a local relation to a particular organ; and without this relation no kind of sensation can be fully realized as a mode of consciousness. And this is all that it is necessary to observe, so long as we are describing consciousness as it is, not constructing it as it might be. Whether any single organ of sense—smell, for instance, or hearing, supposing it to exist isolated from the rest—would be competent to furnish the empirical conditions under which the consciousness of space is realized, is a question which can only be approximately and conjecturally answered by a special examination of each sense. But such an examination would throw but little light on human consciousness as it actually exists. Consciousness is the result of a human intellect acting in conjunction with a human organization; and if we withdraw or mutilate either element, we produce, not an actual man, but a hypothetical monster. A being endowed, according to the hypothesis of Condillac, with a sense of smell only, and identifying himself with his successive sensations (it would be more correct to say, having no notion of self at all), would not, properly speaking, be in any sense a *conscious being*. He would be deficient in the essential conditions of consciousness, the distinction of subject from object, and of objects from each other. To be conscious of a particular sensation, we must know it as such; and to know it as such implies a concomitant knowledge of other sensations as different, and thus of the bodily organism as extended, or as *occupying space*.

Much of what has been said of space is applicable to time also. This is the condition, not merely of external perception, but of the entire consciousness, external and internal alike. Consciousness in every form implies a permanent and a variable element—a continuous self subject to successive modifications. It is thus necessarily manifested as a *change*, and that change as taking place in time. Pure time, like pure space, is not in itself an object of consciousness, but an element which, to be realized in consciousness, must be combined with the results of experience. We can form no notion of time *per se* with no events taking place in it. Time is thus manifested in the form of a relation of successive modes of consciousness to the one conscious self. It might be conjectured with some plausibility that a being not subject to any change of consciousness, or, on the other hand, one not cognisant of his personal identity in the midst of change, would have no idea of time. But then such a being would have no consciousness at all, in the proper sense of the term. Time, like space, cannot be annihilated by any act of thought, and cannot be conceived as subject to any limitation, as having either beginning or end, or as absent from any mode of consciousness. Indeed, these conditions mutually imply each other; for to conceive a limit of time would be to conceive a consciousness in which time is present, preceded or followed by another from which time is absent. Time has thus, in common with space, the characteristics of universality and necessity, which appear to indicate a subjective condition or law of consciousness itself. Like space, too, it is manifested in conjunction with and on the occasion of experience, being manifested simultaneously with the empirical element of change, the apprehension of which constitutes the first step of positive consciousness.[2]

We are not at present concerned with the question whether space and time have any real existence apart from that of the mind which gives these forms to the objects of its consciousness. This question belongs to ontology, not to psychology. Space and time are known to us as formal conditions of consciousness; whether they are anything more than such conditions, is a question which at present we have no means of answering. The laws of consciousness must be primarily manifested as binding upon the conscious mind. As such, they necessarily accompany every manifestation of consciousness; and in their utmost objective reality they could do no more. But we do not deny the real existence of space and time, though at the present stage of our inquiry we are not able to affirm it. We shall hereafter have occasion to consider whether this question can be answered at all. It is sufficient for the present to say that it cannot be answered by psychology.

OF THE MATTER OF INTUITIVE CONSCIOUSNESS.

The matter of intuitive consciousness cannot be specified with the same exactness as the form; for while in all cognate acts of consciousness the form is one and the same, and therefore admits of a distinct examination apart from the several modes of consciousness into which it enters, the matter is the variable element by which one act of consciousness differs from another, and which, therefore, can only be fully analysed by a separate examination of each individual case. The various phenomena of the matter of consciousness, however, admit of being classified and partially described under certain general heads; and such a classification has accordingly been attempted in the distinctions, which form the substance of most psychological treatises, between the various states, operations, and faculties of the human mind.

The matter of intuitive consciousness, in its widest sense, denotes all that comes to the mind from without,—all, in short, that is due to this or that special *experience*. Of experience there are two principal sources: 1. *Sensation*, or *external intuition*, by which we become cognisant of the phenomena connected with our material organization; and, 2. *Internal intuition* (called by Locke *reflection*),[3] by which we become cognisant of the several successive states of our own minds. To the former we owe the materials of our knowledge of what takes place without us; from the latter, in like manner, is derived our knowledge of what takes place within us. The subdivisions of these two constitute the several states and operations of the human mind.

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[1] Space, though not positively conceived as devoid of all contents, is yet necessarily conceived as separable from any given contents, and thus as independent of each in succession.

[2] The apparent paradox, on the one hand, that consciousness must have had a beginning in time, and, on the other, that consciousness is only possible under the form of a change of state, will be further explained in the sequel.

[3] There is an ambiguity in Locke's use of the term *reflection*, which has given rise to considerable misunderstanding. Etymologically, the term should denote a *turning back* of the mind upon an object previously existing, so that the existence of a state of consciousness is

OF SENSATION AND PERCEPTION.

Sensation, in its most general acceptation, is sometimes used to signify the whole of that portion of consciousness which comes to us by means of the bodily organs of sense. *Perception*, too, has been used by various writers in a wider or a narrower sense—sometimes as synonymous with consciousness in general, sometimes as limited to the apprehensions of sense alone.[1] Under the latter limitation it has been found convenient to make a further restriction, and to distinguish between *sensation proper* and *perception proper*.

Sensation proper is the consciousness of certain affections of our body as an animated organism.

Perception proper is the consciousness of the existence of our body as a material organism, and therefore as extended.

The sensitive organism may be considered in two points of view:—1. As belonging to the *ego*, or conscious subject, which, in its actual concrete existence, is susceptible of consciousness only in and by its relation to a bodily organism. 2. As belonging to the *non ego*, or material object of consciousness, from which the mind, as an abstract immaterial being, is logically separable; though, in actual consciousness, the two are always united. The bodily organism is thus the debatable land between self and not-self. In one sense, my eye is a part of my conscious self; for sight is an act of consciousness, and sight cannot exist except by means of the eye. In another sense, my eye is not a part of myself; for a man whose eyes are put out continues to be the same person as before. Hence the organism, as the vehicle of sensation, exhibits in the same act attributes of mind and attributes of body. In the former point of view, the act of sensitive consciousness is regarded as a *sensation*; in the latter, as a *perception*.

Perception is sometimes defined as "the knowledge we obtain, by means of our sensations, of the qualities of matter."[2] This definition may be admitted, if *matter* is understood as comprehending our own bodily organism, as well as the extra-organic objects to which it is related. The former is the only kind of matter that is *immediately* cognisable by the senses. The existence of a material world, distinct from, though related to, our organism, is made known to us, not by the senses themselves, but, as will be noticed hereafter, by the *faculty of locomotion*. Sensation and perception, as above explained, are always correlative to each other; every sensation being accompanied by a consciousness of the extension of the sensitive organism, and this consciousness being a perception. But, though always coexistent, they are not proportionally coexistent. On the contrary, the sensation, when it rises above a certain low degree of intensity, interferes with the perception of its relations, by concentrating the consciousness on its absolute affection alone. Hence Sir William Hamilton, from whom the above remark is taken, has enunciated the important rule, *that, above a certain point, the stronger the sensation, the weaker the perception; and the distincter the perception, the less obtrusive the sensation.* In other words, *though perception proper and sensation proper exist only as they coexist, in the degree or intensity of their existence, they are always found in an inverse ratio to each other.*[3]

OF THE FIVE SENSES.

Sensation and perception, according to the above law, coexist, though in an inverse ratio to each other, in each of the five senses. But in addition to the relation which each bears to the other, when viewed with reference to the same sense, they are also found to be combined in different proportions when one sense is compared with another. In some the sensation so far predominates over the perception, that the sense manifests itself as a source of feeling rather than of knowledge, and has often, though erroneously, been regarded as consisting of the former element only. In others the reverse is the case; the perceptive element, or cognition of an object, predominating over the sensitive element, or consciousness of a personal affection. In this point of view, the senses of smell and taste may be distinguished as especially subjective or sensational; those of hearing and sight as objective or perceptional. Touch, inasmuch as it has no special organ, but is diffused in various degrees over the various parts of the body, will require a separate consideration. In other words, smell and taste are chiefly known as vehicles of the mental emotions of pleasure and pain; hearing and sight, as informing us of the nature of the bodily attributes of sound and colour. Touch may contribute to the one or the other end, according to the part of the body in which it resides, and the manner in which it is brought into exercise.[4]

Of Smell.

In smell, as in the other senses, it is necessary to distinguish between the sensation itself, and its object, which, in ordinary language, are not unfrequently confounded together. Thus we speak of the organ of *smell*, and of the *smell* of a rose, using the same term indifferently to signify the act of inhaling an odour and the odour inhaled. The act of smell, apart from the physiological inquiries connected with it, requires no description, being familiar to every one from his own experience. It will be sufficient for our present purpose to distinguish the sensation from the accompanying perception; and this will be best accomplished by an examination of the object.

The true object of smell is to be found in the odorous particles in contact with the organ. It is incorrect to say that we *smell a rose*, meaning by *a rose* the flower as seen or touched. We smell only the effluvia emanating from the rose and coming in contact with the nervous organism. What these effluvia or odorous emanations are in them-

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distinct from the reflection on that state. In this sense, a sensation, like any other mode of consciousness, may be an object of reflection; and those philosophers who understood Locke in this sense were only consistent in reducing his two sources of ideas to the single one of sensation alone. But, in the greater part of Locke's essay, reflection is treated of in a different sense, namely, as the immediate consciousness of our internal states of mind—a consciousness identical with the existence of those states, and thus forming an original source of ideas.

[1] Thus Locke enumerates sensation and reflection as the two sources of our ideas, meaning by *sensation* what, in the language of Reid, would be sensation and perception together. In this he is followed by Condillac. The distinction between sensation proper and perception proper originated with Reid; but its most accurate development is due to his editor, Sir William Hamilton. From the notes of the latter, the greater part of the remarks in the text have been taken.

[2] Stewart, *Outlines of Moral Philosophy*, sect. 15.

[3] *Reid's Works*, p. 880. The same rule had been in substance previously given by Kant, *Anthropologie*, sect. 20.

[4] This remark of course applies only to the senses as they exist in the human subject. A similar general rule, indeed, probably holds good with regard to the lower animals; but it is differently manifested in the several senses. Of the senses of taste and smell it has been observed by Sir W. Hamilton, that "precisely as in animals these latter senses gain in their objective character as means of knowledge, do they lose in their subjective character as sources of pleasurable or painful sensations. To a dog, for instance, in whom the sense of smell is so acute, all odours seem in themselves to be indifferent." (*Reid's Works*, p. 863.) Compare Kant, *Anthropologie*, sect. 15, whose distinction slightly varies from that given in the text.

selves, natural philosophy is unable to determine. "Although it may be surmised," says Dr Carpenter, "that they consist of particles of extreme minuteness, dissolved as it were in the air, and although this idea seems to derive confirmation from the fact that most odorous substances are volatile, and *vice versa*, yet the most delicate experiments have failed to discover any diminution in weight, in certain substances (as musk) that have been impregnating with their effluvia a large quantity of air for several years; and there are some volatile fluids, such as water, which are entirely inodorous."[1] But whatever these odorous particles may be, it is important to remember that they, and not the bodies from which they proceed, are the proper objects of smell; and, consequently, that this sensation (and the same may be said of all the others) is in fact a modification of touch. Hence it is incorrect to speak, as Aristotle and many subsequent writers have spoken, of the object of smell as perceived through a medium, such as the atmosphere. The atmosphere is not the medium of communication between the sensitive organ and its object, but only the vehicle by which the object is brought into contact with the organ.

Smell conveys to us no knowledge of the existence of extra-organic matter. The only matter of which we are directly conscious in this, as in other actions of sense, is our own organism as extended; and this consciousness constitutes the *perception* of smell, as the consciousness of the same organism as affected constitutes the *sensation*. In the remarks upon the consciousness of space as the form of all sensitive intuition, enough has been said to explain in what sense the consciousness of locality and extension form part of the energy of smell as it actually exists, and to show that the lowest degree of intelligence that is sufficient for sensation proper is sufficient for perception also. But the object perceived is not a quality of body as such, but only the proper action, or rather passion, of our nervous organism; an action or passion of which the external cause is, so far as perception is concerned, wholly unknown, and which may even be excited in a similar manner by totally different causes. This is not so evident in the case of smell as in some others of the senses; yet it is a known fact in physiology that the sensation of smell may be produced in the olfactory nerve by electrical action without the presence of any odorous body. This fact is sufficient to show that the operation of a sense by itself does not afford any legitimate grounds for determining the qualities, or even the existence, of an extra-organic world. On this subject we shall have more to say when we come to treat of the distinction between the primary and secondary qualities of body.

Of Taste.

The principal characteristics of the sense of smell are common to that of taste also. The two senses resemble each other in being both powerful as instruments of feeling, and proportionally weak as sources of information. Tastes, like smells, admit of hardly any classification, except in respect of their relation to the sensitive organism as pleasant or painful. Like smell, too, the sensation appears to be produced by means of sapid particles emitted from the body, and brought into contact with the nerves; and these particles, which constitute the object of the sense of taste, are in their own nature as little known as those of smell, and can as little be regarded as bearing any resemblance to the sensations which they excite. Taste, like smell, is thus a modification of touch; the object in contact with the organ being the sapid particles, and not, as might at first be supposed, the body from which those particles proceed. The body is in contact, not with the nerves, but only with their exterior covering; and in order to produce the distinctive sensation of taste, it appears to be necessary that the sapid particles should be dissolved in the saliva, and thus penetrate through the investments of the papillæ into their substance.[2] But, not to enter here on questions more properly belonging to physiology, it will be sufficient for our present purpose to observe, that taste, like smell, conveys no knowledge of the existence of extra-organic matter, and that the sensation, properly so called, consists in the consciousness of the organism as affected in a particular manner, agreeable or disagreeable; while the perception is to be found in the corresponding consciousness of the locality of the affection in the organism as extended. Though these two are always to a certain extent co-existent, yet the former predominates so far over the latter as to form the principal characteristics of this class of sensations. For this reason, the organs of taste and smell are distinguished as being pre-eminently the sources of *sensation* in the strict sense of the term.[3]

Of Hearing.

In hearing, the functions of sensation and perception are perhaps more nearly balanced than in any other of the senses. The subjective character of various sounds, as sources of pleasure or pain to the hearer, may be contrasted with their objective character, as resembling or differing from each other; and as in the latter relation this sense affords more accurate distinctions than those of taste and smell, so in the former the sensation is less capable of being carried to an extreme degree of pleasure or pain.[4] Hearing, therefore, though contributing in different degrees both to enjoyment and to information, may be characterized as a source of the latter rather than of the former; and if, according to the rule already mentioned, the sensation and the perception are in an inverse ratio to each other, it will follow, that in proportion as our attention is more directed to the discrimination of various sounds from each other, we are less immediately conscious of the pleasure or pain which they are capable of communicating. In hearing, as in the senses previously described, we are directly cognisant, not of the sonorous body, but of the change in the condition of the auditory nerve produced by contact with a medium by which the vibrations are transmitted (the fluid inclosed in the labyrinth of the ear), and hence hearing, like the other senses, is a modification of touch, and does not directly inform us of the existence of any other material object than our own nervous organism. Hence it follows, that neither the *distance* nor the *direction* from which a sound proceeds is immediately perceived by the ear; and this conclusion is confirmed by the facts connected with the exercise of this sense in its uneducated condition, as by children, and occasionally also by adults. The child does not appear to be conscious at first of the direction or distance of voices that attract his attention; and a remarkable instance of the same kind in a grown person is mentioned by Dr Reid. "I remember," he says, "that once lying a-bed, and having been put into a fright, I heard my own heart beat; but I took it to be one knocking at the door, and arose and opened the door more than once, before I discovered that the sound was in my own breast." . . . . "It is probable," he continues, "that, previous to all experience, we should as little know whether a sound came from the right or left, from above or below, from a great or a small distance, as we should know whether it was the sound of a drum, or a bell, or a cart?"[1] In this respect, the sense of hearing presents a remarkable analogy to that of sight; and this property of both will be considered when we come to treat of acquired perceptions.

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[1] *Principles of Human Physiology*, p. 905.

[2] Carpenter's *Principles of Human Physiology*, p. 900.

[3] Kant, *Anthropologie*, sect. 15; Tissot, *Anthropologie*, vol. i., p. 37.

[4] A lover of music might perhaps demur to the conclusion that the pleasures of hearing are less intense than those of taste or smell. In explanation, it should be remembered that we are speaking only of the pleasure conveyed by the sensation itself. The pleasure derived from music is mainly intellectual, and is chiefly derived, not from the sound heard in any one sensation, but from the cognition of its relation to others, which are not heard but remembered; or from associations which may be suggested by, but are not actually contained in, the sound as heard. In short, the natural sensation, which is common to all mankind, must be distinguished from the acquired sensation which is in a great degree the result of education.

Of Sight.

Sight is of all the senses the most communicative as a vehicle of information, and consequently the one in which there is the least immediate consciousness of pleasure or pain in the exercise. Most of the knowledge, however, which this sense, in its matured state, conveys to us, belongs to its acquired, not to its original power, and is the result, not of a direct perception, but of an inference from a perception. In sight, as in the other senses, the direct perception is produced by contact; and the proper object of this sense is not the distant body from which the rays of light are emitted or reflected, but the affection of the organ of sight (the retina and the nervous system connected with it) produced by the rays impinging upon it. The essential characteristics of this affection are *brightness* and *colour*, which, however, are necessarily accompanied by a consciousness of *extension;* for a luminous point, however small, must itself occupy some portion of space, and can be perceived only as in contrast to a surrounding expanse of obscure or differently coloured surface.[2] The immediate object of sight being in contact with the extremities of the optic nerve of the person seeing, it is as impossible for two persons simultaneously to see the same object with their eyes, as to touch the same spot with their fingers; and every movement of the eye which brings a different portion of rays into contact with the organ, produces a different object of vision.[3] The object of vision being thus neither the rays alone nor the organ alone, but the organ as affected by the rays; and the sensation of colour being a purely organic affection, it follows that sight, like the other senses, gives us no immediate knowledge of an extra-organic world; though it is immediately cognisant of extension, and therefore of matter, as presented in the organism itself. Hence we have no immediate perception by sight of the *figure*, the *size*, or the *distance* of bodies; and we cannot in strict accuracy be said to *see* a distant body, such as the sun, at all; though in practice the direct perception becomes so intimately united with the indirect inference, that it is difficult to imagine that either can exist apart from the other. Admitting this view of the true object of sight, which may be regarded as established by physiological as well as psychological testimony,[4] we may notice some remarkable contrasts between the *presented object*, or that which we actually see, and the *represented object*, or that which we appear to see. The presented object is on the surface of the retina; the represented object appears without, and at a greater or less distance from the eye. The presented object is of such a size as can be contained within the spectator's visual organism; the represented object may be many times larger than his whole body. The presented object is a flat surface; the represented object is a solid body. The presented object is inverted; the represented object is erect. The presented object is double, there being a distinct image on the retina of each eye; the represented object is generally single, the two images being in normal vision united into one body. These and other apparent anomalies in the exercise of the senses will be discussed under the head of *acquired perceptions.*

Of Touch and Feeling.

Touch is regarded by many writers as the most objective and the most trustworthy of all our faculties. It has been described as the source of our knowledge of the existence of an external world, and of the real magnitudes, figures, and distances of objects; as the instructor of the other senses, and the corrector of their aberrations. It appears certain, however, that the sense of touch in itself is equally limited in its sphere with the rest of the senses, and that it can convey no other proper perception than that of the existence of its own organism as extended. The sensations of touch, considered by themselves, present no characteristics which can distinguish them from those of the other senses, as regards an immediate cognisance of the external world. Like smell, or sound, or light, they are affections of the nervous system, which may be produced by internal as well as external causes, and which directly indicate no other existence than that of the organized sentient being.[5] The fact is, that in the examination of this faculty, philosophers have often made a two-fold confusion between things in themselves distinct. In the first place, the sense of touch proper, in which the sentient subject is as passive as in any other state of sensation, is confounded with the faculty of locomotion, which originates in a voluntary act of the same subject. In the second place, the sense of touch having no special organ, but being common to all parts of the surface of the body, it has sometimes happened that perceptions have been assumed to be invariable and absolute, which, in truth, are relative to one part only of the organism, and assume a different character in relation to other parts. To mention only one eminent instance out of many, both these confusions occur in Bishop Berkeley's *Essay towards a New Theory of Vision.* That illustrious philosopher distinguishes between two kinds of magnitude, —the one tangible, which is perceived and measured by touch; the other visible, by the mediation of which the former is brought into view. The tangible magnitude he considers to be fixed and invariable, while the visible magnitude changes as we approach to or recede from the object. Hence he concludes that tangible and not visible figures are the objects of geometrical reasoning; the latter having no other use than words have, namely, as signs to suggest the former. Now, in the first place, it is obvious that mere touch, without the power of locomotion, can inform us of no other magnitude than that which corresponds to the touching organ. In point of fact, it informs us only of the extension of the organ itself; but under no possible hypothesis could it inform us of more than the magnitude of that part of a body with which we are actually in contact. In the second place, it has been proved by experiment that the same object will appear of different magnitudes when in contact with different parts of the human body, and consequently that the sense of touch, regarded by itself, is not only variable, but even self-contradictory in its testimony. Hence it follows that the sense of touch alone has no pre-eminence over the other senses as a criterion of truth in relation to a material world beyond our own organism; in fact, like the other senses, it is silent as to the existence of such a world. Touch, however, differs in some remarkable particulars from the other senses. There is no distinct organ appropriated to the tactual sensations alone; and the various parts of the body by which these may be communicated may also be the instruments of other classes of sensations, all of which have been confounded under the general name of "touch" or "feeling." The object of touch proper has no special name, like *sound, colour*, or *smell;* but in itself it is familiar to every one who has experienced the state of consciousness which results from the contact of his own body with another, when not sufficiently violent to rise into a positive sense of pleasure or pain. In this state there is a two-fold consciousness; that part of the bodily organism being known at the same time as *affected* and as *extended.* The former constitutes the *sensation*, the latter the *perception;* and in proportion as the former rises to a higher consciousness of pleasure or pain, the latter grows feebler, though never becoming wholly extinct. This double state, which has no appropriate name, may perhaps be distinguished in its twofold character by the name of *Tactual Impression.* In addition to this may be mentioned other modes of feeling communicated, partly at least, through the same organs, such as those of heat and cold, which have sometimes been regarded as the proper objects of the sense of touch, and the various kinds of pain and pleasure produced by external applications. It will be sufficient for our present purpose to notice, that all of them belong to the class commonly known as *secondary qualities of body;* that is to say, affections of the different parts of the nervous organism, which, as apprehended, have no resemblance to any property of inorganic matter, though generally caused by some unknown power by which that matter is capable of affecting our organs.

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[1] *Inquiry into the Human Mind*, chap. iv., sec. 1. (*Works*, ed. Hamilton, p. 117.)

[2] See Sir W. Hamilton, *Reid's Works*, p. 860.

[3] *Ibid.*, p. 304.

[4] See Sir W. Hamilton, *Reid's Works*, p. 160, 301, 304, 814; and Dr Carpenter, *Principles of Human Physiology*, p. 925, 928 (4th edit.)

[5] See Destutt Tracy, *Elémens d'Idéologie*, p. i., chap. 7; or his follower, Brown, Lecture xxii. Both these authors, however, are wrong in denying an immediate tactual perception of our own organism, though right as regards an extra-organic world.

General Remarks on the Five Senses.

The psychological characteristics of the five senses in general, omitting those which properly belong to physiological inquiries, may be summed up as follows:—The proper function of each and all of them is a *sensation*, or affection of the nervous organism as *animated;* which affection, however, does not, and in all probability cannot, exist in consciousness without an accompanying intellectual cognition of the same organism as *extended* or *occupying space.* This cognition (the *perception* proper) is referred to the intellect rather than to the sense, chiefly for two reasons: Firstly, because it is not, like the sensation proper, limited in each case to a single form of sensibility, but appears as the common condition of consciousness in all. Secondly, because it is not in any case the consciousness of a single object as such, but of a relation either between the parts of the sensible object, viewed as out of each other, or between that object as a whole and the concomitant conditions under which it is presented to the sense. Thus, for example, the rays of light in contact with the retina may be perceived either as forming a visible surface, whose parts are related to each other, or as a luminous spot related to the surrounding obscurity; and even a smell or a sound, whether themselves perceived as extended or not, are at all events discerned in and by their relation to different parts of an extended organism.[1] The sensation and the perception are thus each the necessary condition of the other; and the union of the two is requisite to constitute a state of consciousness. But consciousness is not complete, even when these two elements are united. The consciousness of any mental state (whether of sensation or otherwise) never does, and probably never can take place, without the accompanying consciousness that something else preceded it. This *something* need not be distinctly known as a former state of consciousness (which would make a beginning of consciousness impossible), just as the space to which the object of perception is related need not be distinctly discerned as containing other objects; but every act of consciousness as such is accompanied by the conviction, indefinite it may be, of something having gone before, just as a coloured spot in sight is perceived as having something surrounding it.[2] In other words, every act of consciousness, as such, is presented as a *change in the state of our existence*, not as the beginning of that existence, and thus implies the continuous existence of a permanent self, presented in and through the several modes of consciousness, but not identified with any. We can have no knowledge of an abstract self apart from its successive states of consciousness, nor yet of any one of those states, save as a mode of the existence of one and the same indivisible self. The sensitive consciousness is thus revealed to us as composed of three elements; a permanent self, having a sensitive organism extended in space, and with successive affections of that organism taking place in time. None of these elements, apart from the rest, can be presented or represented in consciousness; and the distinction between sense and intelligence is thus verbal only, not real, constituting, like the concave and convex circumference of a circle, different sides of the same consciousness, but incapable in any act of thought of being considered apart from each other. In the words of Sir William Hamilton,—"It is manifestly impossible to discriminate with any rigour sense from intelligence. Sensitive apprehension is in truth only the recognition by intelligence of the phenomena presented in or through its organs.[3]

The *proper sensibles*—smell, taste, sound, colour, and tactual sensation—all belong to the class commonly called secondary qualities of body, which are in reality affections of the nervous organism, which have no resemblance to any attribute of inorganic bodies. It is true that, in their normal state, they are excited by the presence of such bodies; but that in themselves, as apprehended, they are states of the nervous organism, and not qualities of other bodies, is evident from the fact that they may be abnormally called into existence by any circumstance which produces the appropriate nervous action, even when the ordinary bodily correlative is not present. In fact, as Professor Müller has observed, "*external agencies can give rise to no kind of sensation which cannot also be produced by internal causes, exciting changes in the condition of our nerves.*"[1] Such is the case in the well-known phenomena of dreams, of spectral illusions, of ringing in the ears, of bitterness in the mouth, &c., to which may be added the several artificial means by which various sensations may be produced—light and colours by pressure on the optic nerves, ringing by a blow on the ear, and the sensations of all the senses by electricity.[2] Similar though less striking evidence to the same point is furnished by the familiar instances of the sensation remaining in the organism when the body is withdrawn, or the communication intercepted. Thus a luminous body, passing rapidly backwards and forwards before the eye, appears as a continuous line of light; a rapid succession of sounds will produce a continuous tone; the spectrum of a bright object may be distinctly seen after the eyes are shut, &c. It is manifest, therefore, that the senses cannot in any case furnish direct evidence of the existence or properties of an extra-organic world; for, even if we are compelled by a law of our constitution to suppose the existence of an external cause of our internal states, such a supposition is representative, not presentative,—suggested by, not contained in, the sensation; it gives us no knowledge of the nature of the cause which it suggests, and in some instances, as has been shown, is deceptive even in suggesting its existence.

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[1] Notwithstanding the general opinion of philosophers to the contrary, I am inclined to think that some consciousness of extension is simultaneous with the earliest exercise of sensation. Of course I do not mean that this consciousness is distinct, and can be at that time separated by analysis from its concomitants; but this is equally the case with all the characteristics of sensation. I only mean that the element of locality is there from the beginning, at least as distinctly as anything else, and that it could be detected if the sensation in its original state could be reproduced in a mind sufficiently developed to be capable of analyzing it. In this respect it differs from the acquired perceptions properly so called, such as externality, distance, magnitude, &c., which may be chronologically as well as logically separated from the original sensation. So long as sensations are spoken of as affections of mind only, there is plausible ground for the opposite opinion; not so, however, when they are viewed in their true character, as affections, neither of mind alone nor of matter alone, but of an animated organism, *i.e.*, of mind and matter together. Professor Müller allows that there is a perception of the extension of the organism in sight, touch, taste, and even smell, though slightly, if at all, in hearing. It may be conjectured, however, that the compound action of the two ears in hearing will naturally give rise to some perception of extension, though this may become obliterated in acquired perception, from the attention being withdrawn from it to other sources of information. (See Baly's translation of Müller's *Elements of Physiology*, p. 1073, 1075, 1086.)

[2] Puisque réveillé de l'étourdissement on s'apperçoit de ses perceptions, il faut bien qu'on en ait eu immédiatement auparavant, quoiqu'on ne s'en soit point apperçu; car une perception ne sauroit venir naturellement, que d'une autre perception, comme un mouvement ne peut venir naturellement que d'un mouvement." (Leibnitz, *Monadologie*, sect. 23.) This position, which Leibnitz maintained on metaphysical and psychological grounds, is confirmed by the researches of physiology, which tend to show that consciousness has a physical as well as an intellectual growth; that impressions may be made on the organism which may leave perceptible traces in the subsequent development of consciousness, without having been themselves present to consciousness at all. (See Carpenter's *Human Physiology*, p. 818.) This may, perhaps, help to explain the apparent paradox, on the one hand, that consciousness must have had a beginning in time, and, on the other, that an absolutely first act of consciousness is inconceivable. Thus time is the universal form of consciousness as such.

[3] *Reid's Works*, p. 878.

What, then, it may be asked, is the nature of our sensations as thus described? Are they affections of mind, or of body, or of both? On the one hand, consciousness in all its modes seems manifestly to be a state of mind. On the other hand, sensitive consciousness appears with the concomitant condition of extension, which is an attribute of body. The general voice of modern philosophers has pronounced that sensations, as such, belong to mind, and not to body. This is asserted both by those who admit and by those who deny the existence of perceptible primary qualities of body in addition to the mental sensation.[3] And rightly, so long as by *body* is meant something distinct from our own organism; but wrongly, or at least inaccurately in language, so long as no distinction is made between body as brute matter and body as part of a sentient being. A dead body, though its eyes are open, has no sensation of colour: so far, sight is an affection of mind rather than of body. But a living man, if his eyes are put out, is equally deprived of the sensation: so far it appears to belong to body rather than to mind; for mind in its purest sense,—the abstract, immaterial, personal *ego*,—cannot be conceived as destroyed, or even as in any way diminished, by the deprivation of a bodily organ. But the above inaccuracy of language assumes more than a verbal importance, when it is made, as is sometimes the case, the foundation of theories of perception, as though the distinction which it indicates were strictly, not merely approximately, true. Thus it is argued that we can have no immediate perception of extension in space, "because it is not explained how the mind, which *alone* can have sensation or knowledge, and which certainly is not square itself, is to be made acquainted with the squareness of its own corporeal organ, or of the foreign body."[4] The whole force of the reasoning, and, at the same time, its whole fallacy, lies in the word *alone*. Mind is not *alone* capable of sensation; for it is sentient only in so far as it animates a bodily organism. That a disembodied spirit has consciousness we must indeed believe; at least it is impossible to conceive how spiritual existence can be otherwise manifested; but, at the same time, it is impossible to conceive such consciousness as at all resembling our own, at any rate in the particular phenomena which are conveyed by means of the senses. Sensation, then, is not an affection of mind alone, nor of matter alone, but of an animated organism, *i.e.*, of mind and matter united.[5] How this union is effected; whether the soul as a substance is one or many; whether it has or has not a local habitation; whether, in short, we have any knowledge at all of a pure immaterial being, apart from its modes of consciousness when embodied;—these and similar questions belong to the ontological branch of metaphysics. At present we are concerned only with the phenomena of sensation, and with the soul as the subject of those phenomena in and through its connection with the body. In this respect the soul cannot be assigned to any peculiar bodily organ as its seat, but, as manifesting its existence in sensation, must be regarded as present in all the sensitive organs alike.[6]

To the above account of sensation and perception an obvious objection presents itself, which it is necessary to consider before proceeding further. "The perception as it ought to be," it may be urged, "is very different from the perception as it is. We are told that we only perceive our own organism; we are conscious of actually perceiving things external to our organism. We do not see the image on the retina; we see the object at a distance from the eye. Even in hearing and smell, the object of which we are actually conscious is not presented as an affection of the nerves, but as situated in and proceeding from a distant body." The answer to this objection is to be found in the fact, that in the actual exercise of our senses, in their matured state, we never perform a pure act of perception, but one of perception united with something else. It is as certain as any fact of science can be, that the perception of distance is not originally conveyed by the eye, but is an inference of the understanding derived from certain concomitant visible phenomena, principally from the degree of distinctness of the colour and outline of the object. Yet of this inference we are never conscious in the exercise of our matured senses, but appear to see the distance of objects as immediately as their colour. The most ordinary judgments apparently derived from sense are instances of the same kind. When I say, "I see a horse," in reality I see nothing of the kind. Even granting for the moment that the external object is *seen*, it can be seen only as a coloured body of a certain figure. That the coloured body before me is a horse is not a perception of the sight, but a judgment of the understanding; a judgment which implies acts of memory, of comparison, of conception, &c. Yet we are not conscious of the data from which we make the inference, but refer the entire result to the act of sight alone. These instances sufficiently show the necessity of distinguishing between *original* and *acquired* perceptions; for which purpose we must first consider the operations of that faculty to which our intuitions of external objects as such properly belong.

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[1] *Elements of Physiology*, translated by Baly, p. 1059

[2] See Müller's *Elements of Physiology*, p. 1064; Carpenter's *Principles of Human Physiology*, p. 888; Abercrombie's *Intellectual Powers*, p. 61.

[3] See Descartes, *Principia*, iv. 197; Malebranche, *Recherche*, l. i., ch. x. *sqq.*; Locke, *Essay*, b. ii., ch. 8; Condillac, *Traité des Sensations*, p. iv., ch. 5; Berkeley, *Principles of Human Knowledge*, i. 3; Reid, *Inquiry*, ch. vi., sect. 4, 5, 6; Stewart, *Essays*, ii., chap. ii., sect. 2; Brown, *Lectures*, xxii. Leibnitz speaks more guardedly on this question,—"Il est vrai que la douleur ne ressemble pas aux mouvemens d'une épingle, mais elle peut ressembler fort bien aux mouvemens que cette épingle cause dans notre corps, et representer ces mouvemens dans l'ame, comme je ne doute nullement qu'elle ne fasse." (*Nouveaux Essais*, l. ii., ch. 8.)

[4] Brown, *Lectures*, xxii.

[5] In this respect the language of Aristotle is more accurate than that of the majority of modern philosophers,—Ἐπεὶ δ' οὔτε τῆς ψυχῆς ἴδιον τὸ αἰσθάνεσθαι οὔτε τοῦ σώματος (οὗ γὰρ ἡ δύναμις, τούτου καὶ ἡ ἐνέργεια· ἡ δὲ λεγομένη αἴσθησις, ὡς ἐνέργεια, κίνησίς τις διὰ τοῦ σώματος τῆς ψυχῆς ἐστί) φανερὸν ὡς οὔτε τῆς ψυχῆς τὸ παθος ἴδιον, οὔτ' ἄψυχον σῶμα δυνατὸν αἰσθάνεσθαι. (*De Somno*, chap. 1, sect. 5.)

[6] See Müller's *Elements of Physiology*, p. 1335. In the above remarks, and throughout this article, no notice has been taken of the different functions of the nerves and the sensorium in sensation. This question is confessedly one of the most difficult in physiology, and, in its proper place in that science, one of the most important. But in reference to the present remarks, this question is of little consequence. The visible image, or other sensible impression, is not itself transmitted to the sensorium; and the irritation of the interior nervous system can only serve to arouse the attention to the affection localized at the surface. The notion of a *seat of the soul*, in the literal sense of the term, is utterly meaningless to any but a materialist; and all that the minutest anatomy can hope to discover is the material *occasion* which acts as the immediate stimulant to consciousness. But the consciousness, once aroused, is as capable of acting in one part of the system as in another, and is, in fact, *present* wherever it acts. This is expressed with philosophical accuracy in the words of St Augustine:—"Ideo simplicior est corpore, quia non mole diffunditur per spatium loci, sed in unoquoque corpore, et in toto tota est, et in qualibet ejus parte tota est." (*De Trinitate*, vi. 6.)

OF THE LOCOMOTIVE FACULTY.

The locomotive faculty, which we have next to consider, differs from the senses, both in other respects, and especially in the circumstance that in its exercise, and partly also in its results, it is dependent upon the will of the person exercising it. By this it is not meant that the will is in all cases consciously exercised; that all motion is the result of a knowledge of two alternatives, and a deliberate preference of one of them. This is not always the case in the most undeniably voluntary acts performed in the maturity of our faculties. A man in the midst of a walk, when engaged in conversation or thought, is not distinctly conscious of each successive movement of his limbs; yet there can be no doubt that the acts are his own, as much as when he is attending to and conscious of the exertion, and that, in either case, it depends on himself to continue or discontinue the motion. How far the will itself is free or determined by antecedent causes, is a question which cannot be considered here; but, whatever theory we may adopt upon this point, as regards the actions of men or of brutes, there is an obvious difference between saying, "You may bring a horse to the water, but you cannot make him drink;" and saying, "You may fire a cannon in his ear, but you cannot make him hear," or "You may lay on the whip, but you cannot make him feel." This difference, whatever amount of liberty it may imply, is all that is insisted upon in distinguishing between the exercise of the locomotive faculty and that of the senses.

It is the locomotive faculty which first informs us immediately of the existence and properties of a material world exterior to our organism. This exterior world manifests itself in the form of *something resisting our volition;* and to this general head of *resistance* may be reduced the whole of those attributes which exterior bodies immediately exhibit in their relation to our organism; namely, gravity, cohesion, repulsion, and inertia. This consciousness of our locomotive energy being resisted by something external, though in practice accompanied by the sensation of touch, is so far distinct from that sensation that either may be conceived as taking place without the other. The sensation of touch is a consciousness of an irritation of the nerves spread over the surface of the skin; a consciousness which experience may teach us to connect with a pressure from without, but which may be, and sometimes is, also communicated from within, and which has no immediate relation to the will of the sentient person. The consciousness of resistance, on the other hand, implies a volition to move the limb, and this volition may be conceived as impeded externally without any accompanying organic feeling. The various qualities of the body, moreover, are manifested in proportion to the amount of volition exercised. A slight effort makes known to us the existence of a resisting body: a stronger or more continued effort is followed by a consciousness of a more vigorous resistance, or of a yielding on the part of the opposing body, either wholly or in a certain direction. Hence we obtain a knowledge of the attributes of hardness or softness, of mobility or immobility All these are different manifestations of a relation between self and not-self; between an organized body acted upon by the will, and a foreign body in antagonism to it. This consciousness of resistance to our voluntary motion is something very different from that of a mere inability to move, such as may take place when a stroke of paralysis destroys the power of the will over the bodily motions. We have in it, not the mere negative consciousness of will not followed by motion, but the positive consciousness of will followed by motion, and that motion resisted from without. In this relation both elements are equally *presented*, and one of them is the external body.

The manner in which the locomotive energy may be supposed originally to exert itself, and the foundation which by such exertion would be laid for the education of the sensitive consciousness, even before the latter is called into actual existence, has been graphically described by Professor Müller, in language which I will not attempt to weaken by alteration; though I may remark, in quoting it, that that eminent physiologist has hardly marked with sufficient accuracy the distinction between the sense of resistance and that of touch properly so called; and consequently has made some confusion between the objective and subjective, the presentative and the representative consciousness. "If we imagine a human being, in which—as in the fœtus in utero, for example—the sense of vision has never received any impressions, and in which sensations of touch merely have been excited by impressions made upon its body from without, it is evident that the first obscure idea excited would be no other than that of a sentient passive *self*, in contradistinction to something acting upon it.[1] The uterus, which compels the child to assume a determined position, and gives rise to sensations in it, is also the means of exciting in the sensorium of the child the consciousness of something thus distinct from itself and external to it. But how is the idea of two *exteriors*,—of that which the limbs of the child's body form in relation to its internal self and of the true exterior world,—developed? In a twofold manner: In the first place, the child governs the movement of its limbs, and thus perceives that they are instruments subject to the use and government of its internal *self;* while the resistance which it meets with around is not subject to its will, and therefore gives it the idea of an absolute exterior. Secondly, The child will perceive a difference in the sensations produced according as the parts of its own body touch each other, or as one part of the body only meets with resistance from without. In the first instance, where one arm, for example, touches the other, the resistance is afforded by a part of the child's own body, and the limb thus giving the resistance becomes the subject of sensation as well as the other. The two limbs are in this case external objects of perception and percipient at the same time. In the second instance, the resisting body will be represented to the mind as something external and foreign to the living body, and not subject to the internal *self.* Thus will arise in the mind of the child the idea of a resistance which one part of its own body can offer to another part of its own body, and at the same time the idea of a resistance offered to its body by an absolute *exterior*. In this way is gained the idea of an external world as the cause of sensations.[1] Though the sensations of the being actually inform him only of the states of himself, of his nerves, and of his skin, acted upon by external impressions,[2] yet henceforth the idea of the external cause becomes inseparably associated with the sensation of touch;[3] and such is the condition of sensation in the adult. If we lay our hand upon the table, we become conscious, on a little reflection, that we do not feel the table, but merely that part of the skin which the table touches;[4] but, without this reflection, we confound the sensation of the part of the skin which has received the impression with the idea of the resistance, and we maintain boldly that we feel the table itself, which is not the case. If the hand be now moved over a greater extent of the table's surface, the idea of a larger object than the hand can cover is obtained. If, to encompass the resisting object, the hand require to be moved in different directions and planes, the idea of surfaces applied to each other in different directions is conceived, and thus the notion of an external solid body occupying space is obtained."[5]

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[1] Perhaps it would be more correct to say only, "a sentient passive self, modified in a certain manner." So far as touch alone, without motion, is concerned, it may be doubted whether there can be any consciousness of a something exterior to *self*. It may perhaps be possible to distinguish the one conscious self from its successive modifications; but the relation thus manifested can hardly be described as one of interior and exterior. The sentient self is on each occasion of sensation present in the organism, and has no conscious relation to anything beyond. There may, indeed, be a consciousness of a local relation between different parts of the body successively affected; but these, though exterior to each other, will not thus be recognised as exterior to the conscious self. The relation of interior to exterior can only exist between two bodies occupying space; and, in this case, can only arise when we become conscious of the double *non ego*, of the bodily organism in relation to some other body. This will be the consequent, not the antecedent, of locomotion.

From the consideration of the locomotive faculty, we should pass, by a natural transition, to that of the acquired perceptions, in which the information originally furnished by this faculty is transferred to other modes of consciousness. Before taking this step, however, it will be necessary to say a few words on another organ of sensation, which, in the opinion of some eminent authorities, is entitled to contest with the locomotive faculty the claim of giving rise to our knowledge of the properties of external matter.

OF THE MUSCULAR SENSE.

The motion of a limb, whether free or resisted, being accompanied by certain sensations arising from the contraction or relaxation of the muscles, it has been sometimes thought that to these sensations, and not to the motion which they accompany, is owing our earliest apprehension of the fact of external extension and resistance.[6] A few words on this question will be necessary to complete this portion of our inquiry.

In the first place, it is unquestionable that these muscular sensations exist, and that they are distinct from the proper impressions due to the five commonly acknowledged senses. The feeling of *fatigue*, for example, belongs, partly at least, to this class; but this feeling is only an increased degree of one which accompanies every muscular exertion, and which, in its more moderate forms, is pleasant instead of painful. When we move a limb after a sufficient rest, the motion is accompanied by a sensation similar to, though less intense than, that which ensues when it is moved after long previous exercise. To the same class belongs the sensation which accompanies the act of stretching, which is only another degree of the feeling of muscular tension.[7] In the second place, these sensations may in some cases be the means of indicating to us the fact of the motion; and such is probably the office which they perform in the earliest exercises of the locomotive faculty. As at that stage of our existence our other senses have not yet come into operation, or, at least, have not been developed to that degree which suffices for the perception of foreign bodies, it is clear that the fact of our limb being in motion must be made known to us by some feeling connected with the act itself, not by observation of it from any other centre. We cannot as yet *see* that our limb moves: we must therefore, in some manner, *feel* that it does so; and this, in point of fact, is effected by means of the muscular sensations of the limb itself.[8]

But this is not sufficient to convey a knowledge of external bodies. The muscular sensations, viewed by themselves, are, like all other sensations, merely the consciousness of a particular state of our organism, and do not, any more than other sensations, give us a direct perception of the cause from which they proceed. The muscular sensation that arises when our motion is resisted is not a consciousness of resistance, but of a state of our organism caused by resistance; and it is the state, and not the causation, that we immediately feel; the latter, as in the case of the other senses, being not *presented* in the sensitive act, but *represented* as a consequence of association. Hence, while we grant the existence and the importance of the muscular sensations, we are as far as ever from the knowledge of an extra-organic world. This knowledge depends, not on the relation in which that world stands to our *sensations*, but on that in which it stands to our *volitions*. We will in the first instance to move a limb; the sensation may inform us that the limb obeys our volition; but it is the motion, and not the sensation, which is resisted by the external body. The two are unlike in all their most important features. The sensation is chiefly, if not entirely, a passive state; the motion is an active energy. The sensation is in the organism; the motion is derived from the will. The sensation conveys an immediate knowledge of the *ego;* the motion, when resisted, conveys an immediate knowledge of the *non ego.* I am conscious at one time of a voluntary effort to move; I am conscious also (whether through the muscular sensation or otherwise) that I have overcome the inertia of the limb, and put it in motion; and I am conscious of the amount of effort necessary to effect this purpose. This consciousness contains, as its condition, a concomitant intellectual apprehension of *space*, without which, the effort to move could not be made or willed; and this apprehension appears to be original and inexplicable, as it is implied in the first consciousness of a power of locomotion, prior to its actual exercise. I next become conscious that the motion is resisted from without, and that an additional effort is needed to overcome the resistance and continue the motion. This is an immediate perception of a relation between *self* and *not-self*, between the resisted effort and the resisting object. In this the voluntary energy is the primary source of knowledge; the muscular sensation, the secondary, and possibly the contingent accompaniment. The language of Destutt Tracy,—"Il reste donc constant que le mouvement volontaire nous donne seul un vrai sentiment de resistance,"[1] can hardly be called exaggerated.

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[1] Rather "as existing and resisting our volitions." To describe the external world merely as the *cause of sensations* is to make it no more than a hypothetical object, invented to account for certain states of the subject.

[2] True of the sensations proper, but not of the locomotive volition; and, in the case of the former, the impressions need not be *external.*

[3] How can it be *associated*, unless it has been first *given* without association; *i.e.*, in itself, and not merely in its effect? Otherwise there is a relation with only one related term.

[4] True of the mere feeling; but not of the consciousness that arises when we try to penetrate into the substance of the table, and find ourselves unable to do so.

[5] Müller's *Elements of Physiology*, p. 1080, Baly's translation. The notion of a solid body occupying space, may, however, arise from simpler data than those supposed in the last sentence. This will be considered hereafter, when we treat of the primary qualities of body.

[6] See Brown, Lecture xxii. In giving the prominent place to the muscular sensation, and taking but slight notice of the volition by which it is accompanied, Brown departs from the teaching of his master Destutt Tracy, and in the same degree vitiates the theory.

[7] See Brown, Lecture xxii.; and Mill, *Analysis of the Human Mind*, chap. i., sect. 7.

[8] It does not, however, follow that the muscular sensation is in this case the only possible evidence of the motion. On this point Sir William Hamilton observes:—"Supposing all muscular feeling abolished (the power of moving the muscles at will remaining, however, entire), I hold that the consciousness of the mental motive energy, and of the greater or less degree of such energy requisite, in different circumstances, to accomplish our intention, would of itself enable us always to perceive the fact, and in some degree to measure the amount, of any resistance to our voluntary movements, howbeit the concomitance of certain feelings with the different states of muscular tension renders this cognition not only easier, but, in fact, obtrudes it upon our attention." (*Reid's Works*, p. 864.)

OF THE PRIMARY AND SECONDARY QUALITIES OF BODY.

The theory of the action of our senses, and of their relation to the material world, would be incomplete without some notice of a famous distinction which has played an important part in various systems of philosophy,—the distinction between primary and secondary qualities of body. The history of this distinction, under various names, in ancient and modern times, has been given at considerable length in a learned note appended to Sir William Hamilton's edition of Reid's works, to which we must content ourselves with referring. Our limits will only allow a few remarks on the nature of the distinction itself, and its relation to the theory of perception which has been adopted in the preceding pages.

By modern philosophers the distinction between these two classes of qualities has been based, sometimes on a psychological, sometimes on a physical principle. In the former point of view, the primary qualities have been distinguished as those which cannot by any act of thought be separated from the conception of body, being essential to that conception itself, in whatever relation it may be viewed; while the secondary qualities are mere modifications of the primary, by which the bodies are enabled to produce certain sensations in us. In the latter point of view, the primary qualities are considered to be such as really exist, in the bodies themselves, in the same manner in which they are perceived by us; whereas the secondary qualities are but the occult causes of certain sensations, which, as experienced, bear no resemblance to the powers by which they are produced. Under the former class are comprehended extension and solidity, to which have sometimes been added figure, number, motion and rest,[2] hardness and softness, roughness and smoothness.[3]

Against the first of the above principles of distinction it has been objected that some secondary qualities, as well as the primary, are inseparable from the conception of body. Thus colour, of some kind or other, accompanies every perception, and even every imagination of extended substance; and of two contradictory qualities, one or other must be attributed to every object.[4] Against the second principle it may be objected that, even if we admit that in perception we are immediately conscious of the existence of a body as presented, still we know not what any of its qualities may be in themselves, out of relation to our faculties. Both mind and matter may be immediately present in an act of perception, yet the object perceived may be, like a chemical compound, the result of a relation between the two, and may resemble neither of the elements from which it is produced. We can never be certain how much of the perceived phenomena of a body depends on the constitution of our own faculties, and how much belongs to the absolute nature of the body irrespectively of its relation to us. To determine this point, it would be necessary that we should perceive it without our faculties.

Yet both the above principles of distinction are fundamentally sound, though, to free them from misapprehension, they require a somewhat different explanation and application from that which is usually given. The *body* which is directly perceived by the senses is not inanimate matter, but our own organism; and of this, as extended, we have an immediate consciousness in every act of perception. Hence the distinction between primary and secondary qualities as perceived by the senses, if it is tenable at all, must be tenable only in relation to certain qualities existing in our own organism. We can therefore no longer distinguish between attributes existing in bodies, and powers of affecting our sensitive organism; for the *body* in relation to which the distinction has to be made is not that which affects, but that which is affected. In this point of view, it is obvious that colour, for example, is a quality of body, as well as extension. Our visual organism is presented in the act of sight as *extended* and as *coloured.* We cannot say that the extension belongs to the inanimate, the colour to the animated body; for of the inanimate body the senses tell us nothing. Nor yet can we describe the one as an attribute of body *per se*, the other of body in relation to our senses; for the whole nervous organism, as such, exists for us only as it is perceived, and is perceived only as it is affected. Destroy or alter the faculty of sense, and the whole organism of sight, as it is perceived in sensation, exists no more, or exists in a different manner.

The true ground of distinction between primary and secondary qualities of body is, we think, to be found in the fact, that some attributes of body are presented in the exercise of all the senses alike, while others are peculiar to one sense only. In every act of sensation we are conscious of our own organism as extended or occupying space. In the act of sight we are conscious of it as coloured. The two impressions, when once acquired, may be inseparable from each other; but the first may be acquired without the second, as in the case of a man totally blind, who would have a knowledge of extension, but not of colour.[5] Hence the former class of attributes are essential to our conception of body, and indeed form that conception: the latter are accidental in so far as the conception of body may exist without them; though, when the association between the two has once been formed, it may not be possible to separate them by any subsequent act of thought.

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[1] *Elémens d'Idéologie*, p. 162.

[2] As by Locke, *Essay*, b. ii., chap. viii., sect. 9.

[3] As by Reid, *Inquiry*, chap. v., sect. 4; and by Stewart, *Essay*, b. ii., chap. ii., sect. 2.

[4] Sir W. Hamilton, *Reid's Works*, p. 839.

[5] Sir W. Hamilton asserts that "light and darkness, white and black, are, in this relation, all equally colours;" and this is true, when the sensation of both has been once given. But if objects are only discerned by difference, a man totally blind could not be said to have a consciousness of darkness as such, or to associate its idea with the positive impressions derived from the other senses. Ordinary blindness, however, is not a total privation of the sense of colour.

We are thus brought back to the old Aristotelian distinction between *common* and *proper sensibles*, which has been pointed out by Sir William Hamilton as in substance identical with the modern distinction between primary and secondary qualities. In this point of view, the secondary qualities of body may be easily indicated. To this class belong all the affections peculiar to certain parts of our sensitive organism, whether as the proper objects of the respective senses, or as the accidental accompaniments of certain sensations. "Such are the idiopathic affections of our several organs of sense, as colour, sound, flavour, savour, and tactual sensation; such are the feelings from heat, electricity, galvanism, &c.; nor need it be added, such are the muscular and cutaneous sensations which accompany the exercise of the locomotive faculty. Such, though less directly the result of foreign causes, are titillation, sneezing, horripilation, shuddering, the feeling of what is called setting the teeth on edge, &c., &c. Such, in fine, are all the various sensations of bodily pleasure and pain determined by the action of external stimuli."[1]

The primary qualities require somewhat more consideration to determine them. They are the universal attributes of body, common to every mode of its existence as an object of consciousness. Hence they are not, properly speaking, known by sense, but by intellect, having no special organ adapted to their perception, but being equally present in every exercise of the bodily senses. Hence, too, they cannot, in their pure form, be depicted to the sense or the imagination, but require, in every instance, to be united with one or other of the secondary qualities which are the proper objects of the several senses. Pure extension, for example, is not an object of sight or touch, but only visible or tangible extension; *i.e.*, extension combined with colour or tactual sensation. The perception of the primary qualities, in its original manifestation, is in fact an intellectual cognition of the relations between the several parts of our sensitive organism; and, as such, both implies a present consciousness of that organism as affected, and is implied by it. For, on the one hand, the consciousness of a relation implies the simultaneous consciousness of the objects related; and, on the other hand, the consciousness of an object as such implies so much of relation to other objects as is necessary to its distinct cognition. A coloured surface, for instance, can only be perceived as composed of several coloured points exterior to each other; and a coloured point can only be discerned as forming a portion of a coloured surface. The primary and secondary qualities are thus necessarily perceived in conjunction with each other; though the primary constitute the permanent element, implied in the cognition of body in general; the secondary constitute the variable element, implied in the cognition of body by this or that sense.

The primary qualities of body may be all included under the one general head of *relation to space.* This implies the twofold condition of,—1. *Solidity*, or occupation of space in the three dimensions of length, breadth, and thickness; 2. *Being contained in space*, or surrounded by space on every side.[2] Though the sensible affection, as confined to the surface of the organism, may appear at first sight to indicate two dimensions only, yet it is obvious, on a moment's reflection, that the intelligible relation of parts to parts which necessarily accompanies the affection, is only possible under the condition of a simultaneous immediate consciousness of solidity. Space, in all its dimensions, is the form of all our perceptions of sense: a surface, or even a visible point, can only be perceived as occupying a portion of space, and as surrounded by space on all sides of it. It is impossible to conceive a surface as having no space behind or before it, or as not breaking the continuity of that space, and thus occupying a part of it. The geometrical line which has length without breadth, and the geometrical surface which has length and breadth without thickness, are, as objects of perception, equally inconceivable with the geometrical point which has no magnitude;[3] though it is possible logically to distinguish between these various elements of body, and to ascertain the special properties of each. We have in this circumstance a further confirmation of the character which has throughout these pages been assigned to space, as an *à priori* condition of consciousness, manifested on the occasion of experience, but in no way to be evolved from it.

From the general attribute of solidity or occupation of space, in its two constituent features of *geometrical solidity* or trinal extension, and *physical solidity* or ultimate incompressibility, Sir W. Hamilton has deduced the three necessary relations of *number* or *divisibility*, *size* or *magnitude*, and *shape* or *figure;* and from the correlative attribute of being contained in space, those of *mobility* and *situation.* These may be all regarded as primary qualities of body, involved in, and deducible by analysis from, the conception of body in general as presented in every act of sensitive perception.

Those attributes which are immediately perceived as existing in extra-organic bodies are distinguished by Sir W. Hamilton under the name of *secundo-primary qualities.* These are not essential constituents of the conception of body in general, but attributes contingently observed to exist in bodies in relation to our organism. They are all contained under the general head of *resistance* or *pressure*, and are immediately discerned only by means of the locomotive faculty. To this general head belong the attributes of *weight*, *cohesion*, *inertia*, and *repulsion*, all of which are made known to us as different modes of resistance to our locomotive energy. It is by the apprehension of the secundo-primary, not by that of the primary qualities, that we immediately learn the existence and nature of an extra-organic world. We are conscious, to use the words of Sir W. Hamilton, "that our locomotive energy is resisted, and not resisted by aught in our organism itself. In the consciousness of being thus resisted is involved, as a correlative, the consciousness of a resisting something external to our organism. Both are therefore conjunctly apprehended."[4] For a more detailed exposition of this important subject, which our limits do not permit us to treat at greater length, the reader is referred to the dissertations of Sir William Hamilton.[5] It only remains for us to sum up briefly the substance of the above remarks.

By *primary qualities of body* must not be understood qualities of body *per se*, as it exists *out of relation to our faculties;* for of body in this sense we have not, and cannot have, any knowledge. The nearest approximation which we can make to a conception of body *per se* is that of body as it appears *in relation to all our faculties;* and, consequently, the primary qualities can only be directly given as existing in our own organism, which is the only body of which we are immediately cognisant in every act of exter nal perception. The secundo-primary and the secondary qualities are not in this sense qualities of body *per se*, being given only in certain special modes of cognition; the former as attributes of an extra-organic substance resisting our locomotive energy, the latter as affections of our organism in this or that particular state of sensation. The former are thus the essential constituents of our empirical notion of body, from whatever form of experience it may be derived; the latter are attributes superadded to that notion, as manifested by body in certain special relations only.

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[1] Sir W. Hamilton, *Reid's Works*, p. 854 (slightly altered from the original).

[2] Sir W. Hamilton, *Reid's Works*, p. 847.

[3] This is perfectly consistent with the fact, to be noticed hereafter, that the *actual perception* of solidity by sight is not original, but acquired.

[4] *Reid's Works*, p. 882.

[5] *Reid's Works*, notes D and D*.

But though the primary qualities of body as such are immediately given only as existing in our own organism, it is obvious that they are apprehended as forming the essential attributes of all matter alike, organic or otherwise; for the body which resists our locomotive energy can only do so as occupying a portion of space into which we attempt to penetrate, and thus as possessing the same primary qualities with the organism to which it is related. The secondary qualities, too, though immediately apprehended only as affections of our organism, are, in the later development of consciousness, necessarily associated with exterior objects. The nature of this association next claims our attention, as that which gives rise to the important phenomena of acquired perception.

OF THE ACQUIRED PERCEPTIONS.

The examination of the acquired perceptions should, in strict accuracy, be undertaken in connection with the representative, not with the presentative consciousness. They are not, properly speaking, *given* in the sensitive act to which they are supposed to belong, but *inferred* by the understanding, according to a law of association, from the presence of something else. But inasmuch as the inference is one which is never consciously performed; as it takes place by a necessary law of our mental constitution at a period too early to leave any trace in the memory; as, consequently, in the complex acts of our matured consciousness the inferred elements are not directly distinguishable from the data which suggest them; and as the explanation of the former is intimately connected with the preceding remarks on the latter, it will be better to sacrifice the strictly logical arrangement, in order to present in a more connected view the entire series of phenomena usually referred to the evidence of the senses.

It has been already observed that, in the exercise of our faculties in their mature state, no perception occurs pure and isolated, but is, in all cases, united with an act of judgment or inference. To ascertain by actual experience the relative proportions of these ingredients, so as to separate the independent acts of the senses from the results of their education, it would be necessary to have an exact recollection of our first impressions as they existed before the formation of habits. Nay, even this, were it possible, would be hardly sufficient; as it may be questioned whether the education of the senses does not in some respects precede even the first occasions of their exercise. From what has been said in treating of the locomotive faculty, it appears that the sense of sight, for example, can never be said to have existed in a wholly uneducated state; inasmuch as certain obscure notions of an external world already exist, and have made their influence felt, before the eyes of the child have come in contact with the light, or its acts been exposed to the observation of others. When, in the absence of experience of the simple, we attempt to supply its place by analysis of the compound, it must be borne in mind that the results at which we arrive will represent a theoretical rather than an actual process, and that some of the conclusions elicited by the theory will be only approximately true in practice. It must not be supposed, for instance, that the several stages through which the sense of sight is represented as passing, actually occur as distinct phenomena of vision during the unremembered days of infancy. When theory declares that the object which we really see is in the organ of sight, it does not follow that the infant has ever actually seen it there. The approximate truth, that the perception of distance is of gradual acquisition, may be ascertained by positive observation; but no observation can tell us whether the actual exercise of sight began with the first or with a later member of the series. The remark which we have before had occasion to make, that the distinctions of psychology represent the elements of consciousness rather than separate acts, is equally applicable here.

Of the acquired perceptions, those of vision are by far the most important; so much so, that it will be sufficient to notice a few of the principal of these, leaving the reader to apply our observations, *mutatis mutandis*, to the other senses. The principle which must guide him in making the application is that which we have more than once had occasion to repeat; namely, *that no sense, in its original state, informs us of anything more than certain states of our own organism.* In addition to this, it will be necessary to bear in mind another principle of no less importance; namely, *that all representation must be founded on a presentation;* in other words, *that nothing can be inferred in connection with one phenomenon of consciousness which has not been given in connection with another.* The examination of this principle belongs to a later stage of our inquiry. For the present we must content ourselves with taking it for granted.

Among the acquired perceptions of the sense of sight, the most important are the following:—1. The perception of an *external field of vision* distinct from the retina, and the consequent judgments concerning the *distance* and *magnitude* of objects in that field. 2. The perception of the *unity* of a visible object, which presents a separate image to each retina. 3. The perception of the object as *solid* or extended in three dimensions of space, and of its *figure* or boundary in each direction. 4. The perception of its *position*, which is the reverse of that of its image on the retina. A few remarks on each of these will, it is hoped, furnish sufficient information for the explanation of acquired perceptions in general.

I. *Field of vision.*—The true or perceived field of vision is the surface of the retina itself; and this may, in certain cases, be actually discerned as such. Thus, the sensation of darkness is the consciousness of the condition of the retina in a state of repose; and in this there is no perception of any field of vision exterior to the retina itself. The apparent or inferred field of vision is a space of greater or less extent, exterior to the eye, on which the images of the retina are projected by an act of the mind. In the majority of cases, we appear to perceive this field immediately; but many observations have been adduced to show that this apparent perception is not part of the original faculty of sight. An infant appears at first to have no perception by sight of the distance of objects, but stretches out its hands towards distant and near bodies alike. The youth who was couched by Cheselden saw at first all objects in one plane, and apparently touching the eye. It is true that the patient in this instance saw the objects as *on* not *in* the eye; and this may, perhaps, be the case with the infant also; but it must be remembered that the ideas of externality and distance are already partially acquired by the locomotive faculty before the sense of sight comes into exercise. From these approximate facts, joined to what we know of the theory of vision, we may conclude, with some probability, that a being destitute of the power of motion would, on first opening his eyes, discern nothing but the images existing on the surface of the retina.

But, when the knowledge of an external world has been once given by the locomotive faculty, the education of the sense of vision follows rapidly and imperceptibly. A certain image on the retina accompanies the perception of an object in contact with the hand. The object is pushed further off, and the size and outline of the image undergo a corresponding change. The hand is placed over the object, and its image takes the place of the other. It is placed over the eye, and the images vanish altogether. Certain sensations of sight are thus at first associated with certain perceptions of distance; then suggest those perceptions when the latter are not immediately present; and finally, as the process becomes more familiar, are substituted for them. Something similar to this takes place more perceptibly in some of the associations of ideas which are formed at a later period. In many cases, where the association is frequent, the antecedent is gradually forgotten, and the attention wholly fixed on the consequent. There is no original connection between the meaning of a word and its sound, or between the sound and the written characters by which it is represented to the eye; yet the sight of certain black figures on a white ground suggests to the child, first the sound, and, through the sound, the meaning. At a later stage the intermediate links of the chain are forgotten; the sound vanishes entirely; the form of the letter is scarcely, if at all, noticed; and the sight of the printed page plunges us at once into communion with the thoughts of the writer. Yet the mere visual perception remains as it was, one and the same to the man who can read and to the man who cannot. All beyond this is acquired by habit; and the process, when most familiar and most imperceptible, is in its successive steps precisely the same as in those early days when we painfully combined distinct letters into syllables, and distinct syllables into words, and distinct words into sentences. The principal difference which distinguishes this and similar operations from the acquired perceptions of sight is, that the associations are formed in the one case consciously, after the mind has acquired a power of reflecting on its own operations, and of acting in consequence of reflection; in the other, unconsciously, by an instinctive law of our constitution. Hence the latter may be described as a natural association common to all men; the former, as an artificial association peculiar to the educated. Yet our natural powers are not, as natural, necessarily born with us. It is natural for man to see distant objects; in the same way as it is natural for him to walk upright and to use his hands. Yet there was a time when he could not discern distances by the eye; just as there was a time when he crawled on all fours, and employed his hand for no other purpose than that of sucking its extremities.

The following remarks of Professor Müller are important, in illustration of the phenomenon in question:—"Several physiologists—as Tourtal, Volkmann, and Bartels—suppose the interpretation of the sensations of the retina, as objects forming part of the exterior world, to be a faculty of the sense of vision itself. But what, in the first place, constitutes the external world? Since, in the first acts of vision, the image of the individual's own body cannot be distinguished from those of other bodies, the referring of the sensations of vision to something external can be nothing else than the discrimination between the sensations of vision and the subject of them,—between the sensations and the sentient *self*. It is by the operations of the judgment that the objects of vision are recognised as exterior to the body of the individual. . . . It is said that the new-born infant perceives from the first that the objects of vision are external to its body and to its eye; but the infant perceives neither its own eye nor its body in the form of sensations of vision, and only learns by experience which of the images which it sees is its own body. We can therefore only say, that the new-born infant distinguishes the sensations from the sentient *self;* and in this sense only does it perceive the sensation as something external. In brutes, the co-operation of instinct renders this reaction of the sensorium under the impression of external objects much less indefinite; for the young animal soon applies itself to the nipple of the mother; so that its sensorium must be the seat of an innate impulse to attain to the image, which it sees, and which is an object, or something external to the sentient self, by appropriate movements. Though the new-born infant be at first unable to distinguish between the image of its own body and those of external objects, it will soon remark that certain images in the field of vision are constantly reappearing, and that these images move when its body is voluntarily moved. These are images of parts of its own body. All the other images in the field of vision either change quite independently of the body of the infant, or the changes which they undergo do not correspond with its voluntary movements. These are images of objects appertaining to the external world, which, now recognised as existing in a space external to the body of the individual, are henceforth continually presenting themselves in this space, which, according to the conception of the mind, is subject to the operations of vision. Of the eye, as the organ of vision, the new-born infant knows nothing."[1]

The field of vision being thus by association perceived as external to the eye, our judgment of the relative *distance* and *magnitude* of objects within that field is determined by similar associations. That of distance is an inference chiefly drawn, in the first instance, from the degrees of distinctness in the colour and outline of the objects, aided, perhaps, in the case of near objects, by the muscular sensations accompanying the convergence of the optic axes.[2] That of magnitude may be considered as partly original, partly acquired. Original, in so far as there is a difference in the size of the object actually perceived (*i.e.*, the image on the retina), dependent upon the visual angle made by the central rays of two pencils of light from the extreme points of a luminous body, intersecting after refraction within the eye: acquired, inasmuch as the inferred magnitude of the external object is the result of a combination of the size of its image with other phenomena, chiefly with those which give rise to our estimate of its distance. This is, in substance, the theory of distance and magnitude first proposed by Bishop Berkeley,—a theory which, while it has been amended and completed in some of its minor details by the discoveries of modern science, remains in its essential features unshaken.

II. *Single vision with two eyes.*—The above remarks are also applicable in a great degree to the phenomenon of single vision with two eyes; a phenomenon which many eminent physiologists have referred to a special provision in the structure of the visual apparatus,[3] but which is sufficiently proved by the observations and experiments of Professor Wheatstone to be an inference from the mental combination of the two images actually seen. To this combination it is necessary that the two images should fall on portions of the two retinæ which have been accustomed to act in concert; and the principle on which it mainly depends is doubtless the association of a single perception of resistance with the double image of the corresponding visible phenomena.[4]

III. *Solidity and Figure.*—The perceptions of solidity and figure are results of the same law of association. The former, as Professor Wheatstone's experiments show, is, like the unity of the object, the effect of the combination of the two visible images, and depends, as far as sight is concerned, upon the different perspective exhibited by the projection of each. The phenomena of the stereoscope present a now familiar illustration of this; two plane projections being, by means of this instrument, made to act upon the eye in the same manner that solid figures do in ordinary vision; and the two being, by an act of the mind, combined into the appearance of one external solid body.[1] The perception of resistance, however, has also some share in the origin of this association. Figure, like magnitude, is partly an original, partly an acquired perception. Plane figures, such as a square or a circle, can be depicted on the surface of the retina, and can thus be distinguished from each other by the original power of the sense of sight. Solid figures, such as a sphere or a cube, are discerned in a great measure by the simultaneous use of both eyes, though the accuracy of the discrimination is, no doubt, assisted by associations derived from touch assisted by motion.[2]

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[1] *Elements of Physiology*, p. 1168.

[2] Carpenter, *Principles of Human Physiology*, p. 922.

[3] See Müller's *Elements of Physiology*, p. 1197.

[4] See Dr Baly's remarks in his translation of Müller's *Elements of Physiology*, p. 1205; and Carpenter's *Principles of Human Physiology*, p. 917.

IV. *Erect vision.*—The explanation of the erect position of external objects has been attempted in various ways, none of which, however, can be considered as quite satisfactory.[3] It seems to be a law of the mind, in projecting images beyond the retina, to follow in some degree the course of the rays, and thus to produce an inverted impression when the image is projected beyond the point where the rays intersect. But to investigate this and similar points fully, it would be necessary to know the exact relations of mind and body to each other in the act of sensation. This is impossible, as we cannot trace the action of the mind apart from that of the organism. The explanation of many of the phenomena of sensation probably depend on some inscrutable condition of consciousness, which no examination of the mere nervous organism is able to reveal to us. "There is," says Mr Morell, "a perilous distance for the materialist to travel between the retina and the living soul. The eye does not see of itself, neither, if the optic nerve be severed, can any visual perception reach the mind. How, then, we may ask, can the image on the retina travel along the nerve, and impress the brain with its own form and hue? The moment we get beyond the mere *mechanism* of the case, our power of tracing the image is lost, and we can only detect at the other, or spiritual end of the process, a mental phenomenon, differing as widely as possible from the mere material substance without."[4]

The acquired perceptions of the other senses may be explained on the same principles. Such, for instance, are the judgments which we form of the direction and distance of an object by the hearing or the smell; these two senses having, like that of sight, both an original and an acquired field for their exercise. Cognate to the subject of acquired perceptions is that of acquired sensations. The feelings of pleasure and pain, which an object imparts through the senses, may be as much the result of practice and association as the information which we gain by the same means concerning its nature. Instances of this may be found in the artificial tastes which we gain by the constant use of objects which at first were considered as indifferent or disagreeable; and, again, in the strong feelings of dislike with which we often regard various sensations, solely in consequence of some early association. And hence it will often be the case that the different degrees of pleasure which the several senses are capable of affording to an educated man, will by no means correspond to those which they materially impart as vehicles of mere animal enjoyment. Thus the senses of sight and hearing, which are less intense than the other senses in the merely nervous affections which they are calculated to excite, are, notwithstanding, the vehicles of a mixed enjoyment (partly sensitive, partly intellectual) of a far higher order. But the pleasure which we enjoy from the sight of beautiful scenery, or from the hearing of music, is something very different from the natural sensation, or affection of the nervous organism. The natural sensation is limited to that amount of enjoyment of which the sense is susceptible at the moment of its exercise. When our eyes are gratified by a variety of visible objects, or our ears by a succession of sounds, the memory, and not the sensation, plays the principal part. We see the various objects, we hear the various sounds, *in succession;* though by an act of thought we imperceptibly combine them into a single whole. But the *discernment of relations* is in no case a work of sense; and beauty and deformity, harmony and discord, are almost entirely the result of *relations.* To estimate the merely sensual pleasure imparted by sight and hearing, we must suppose the eye to be limited to a succession of detached colours, and the ear to a succession of isolated sounds, with no consciousness of any relation between them, and no power of comparing the past with the present. This distinction between original and acquired sensations has been perhaps too much neglected in the various attempts that have been made to construct an exact philosophy of taste.

OF ATTENTION.

That sensation, as before observed, is neither a purely bodily nor a purely mental affection—that it belongs neither to the nervous organism alone, nor yet exclusively to the active self by which that organism is animated, but to that mysterious union of both, whose elements and laws philosophy has ever failed, and probably ever will fail, to penetrate—appears conspicuously when we come to examine two states of consciousness which appear to form the connecting links between the external and the internal affections, between the passive and the active elements of our nature—partaking of both, and identical with neither. These two are *attention* and *imagination.* Attention, in particular, partakes of this twofold character in a remarkable degree. To a hasty inspection it appears as if the operation of this faculty were at once the antecedent and the consequent of the sensible impression, as if the mind were at the same time active and passive in its production. It appears certain, on the one hand, that, in order to arouse the attention to any sensible phenomenon, that phenomenon must first be presented to consciousness; while, on the other hand, it has been argued, with some plausibility, that unless the attention be previously aroused, consciousness has no intimation of the existence of the phenomenon at all. All the physical conditions of sensation may exist in full perfection, without any corresponding impression being produced upon the mind. "When two persons," says Reid, "are engaged in interesting discourse, the clock strikes within their hearing, to which they give no attention. What is the consequence? The next minute they know not whether the clock struck or not. Yet their ears were not shut. The usual impression was made upon the organ of hearing, and upon the auditory nerve and brain; but, from inattention, the sound either was not perceived, or passed in the twinkling of an eye, without leaving the least vestige in the memory."[1] Of the two alternatives here offered to our choice, the latter is adopted by Dr Reid's successor as the more accurate explanation of the phenomenon. That attention is not necessary to the existence of a sensation in the consciousness seems at first sight manifest, both *à priori*, because a phenomenon must exist before the attention can be aroused to observe it, and *à posteriori*, from the very narrow limits within which experience testifies that our power over our own sensations is confined. When the mind is unoccupied, the slightest and most familiar sounds will make themselves heard as a matter of course. It is not necessary that the attention should be previously directed towards the object from which the sound proceeds; it is sufficient that it be not engaged with any other object. A louder or more unusual sound forces itself on the consciousness, however much the attention may be engaged elsewhere. The striking of a clock may be unheard during an interesting discourse; but the report of a gun, or any unwonted noise, will be heard in spite of it. These and other considerations may be urged in favour of the hypothesis so ably maintained by Dugald Stewart,—namely, that we are in all cases conscious of the sensation, but are not always able to recollect that we have been conscious. "The true state of the fact," says that distinguished philosopher, "I apprehend, is, that the mind may think and will, without attending to its thoughts and volitions, so as to be able afterwards to recollect them. Nor is this merely verbal criticism; for there is an important difference between consciousness and attention, which it is very necessary to keep in view, in order to think upon this subject with any degree of precision. The one is an involuntary state of the mind; the other is a voluntary act: the one has no immediate connection with the memory; but the other is so essentially subservient to it, that without some degree of it, the ideas and perceptions which pass through the mind seem to leave no trace behind them. When two persons are speaking to us at once, we can attend to either of them at pleasure without being much disturbed by the other. If we attempt to listen to both, we can understand neither. The fact seems to be, that when we attend constantly to one of the speakers, the words spoken by the other make no impression on the memory, in consequence of our not attending to them, and affect us as little as if they had not been uttered. This power, however, of the mind to attend to either speaker at pleasure, supposes that it is, at one and the same time, conscious of the sensations which both produce. Another well-known fact may be of use in illustrating the same distinction. A person who accidentally loses his sight never fails to improve gradually in the sensibility of his touch. Now there are only two ways of explaining this. The one is, that in consequence of the loss of the one sense, some change takes place in the physical constitution of the body, so as to improve a different organ of perception. The other, that the mind gradually acquires a power of attending to and remembering those slighter sensations of which it was formerly conscious, but which, from our habits of inattention, made no impression whatever on the memory. No one, surely, can hesitate for a moment in pronouncing which of these two suppositions is the more philosophical."[2]

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[1] This explanation is of course inapplicable to the case of persons who have the sight of one eye only. Here, however, the same perception of solidity will be produced, partly by the associations suggested by resistance, and partly by the different perspective of the projection, consequent on changes in the position of the single eye.

[2] Molyneux proposed to Locke the question, whether a person born blind, who was able by touch to distinguish a cube from a sphere, would, on suddenly obtaining his sight, be able to distinguish them by the latter sense. (See Locke, *Essay*, b. ii., chap. ix.) Professor Müller finds it "difficult to conceive wherefore these two philosophers answered the problem in the negative." That figures, solid as well as plane, can be distinguished by sight alone, when the perception of an external field of vision has once been acquired, seems unquestionable; but the real problem is to determine whether each perception of sight can be at once identified with the corresponding perception of touch. This may in general be doubted, though this particular instance may possibly not be a case in point. (See Sir W. Hamilton, *Reid's Works*, p. 137.)

[3] Sir David Brewster's theory of the line of visible direction is objected to on physiological grounds by Dr Carpenter, *Human Physiology*, p. 916. That proposed by Professor Müller, and adopted by Dr Carpenter, may be briefly stated thus. Up and down, right and left, are relative terms; therefore the inversion of everything is equivalent to the inversion of nothing. This explanation, however, does not tell us why the inversion takes place, but only accounts for the fact of our not noticing it. The fact still remains unexplained, that the external object and the image on the retina are, *to the eye of a stranger*, in a position the reverse of each other. *Query*—Are they likewise so *in different stages of the vision of the person himself?* This we have as yet no means of determining.

[4] *Elements of Psychology*, p. 131.

But this ingenious reasoning is not quite so conclusive as at first sight it appears to be. It proves clearly that the attention cannot be directed to an object in contact with an organ of sense unless something intervenes to arouse it; but it assumes without proof that this something must itself be a phenomenon of consciousness. The question remains, Is the phenomenon of which we become fully conscious by attention the *same phenomenon* that it was before we attended to it? or has attention itself added an element which brings it within the sphere of consciousness? It seems at first sight a paradox to maintain that our consciousness can be stimulated by anything of which we are not conscious. Yet this apparent paradox is a fact which in some degree takes place at every moment of our lives. When we look at the smallest visible point of light, this is obviously compounded of parts so small as to be invisible; yet each of these contributes its share to the sum total of consciousness. When we see a distant forest, the indistinct impression of green is made up of the greenness of every individual leaf, not one of which could be singly discerned. The theory of *latent modifications of mind*, or, as they are called by Leibnitz, *obscure representations*, which is well calculated to explain many of the most curious phenomena of consciousness, has been almost entirely neglected by the philosophers of this country; yet it is one which, though in most of its details belonging to physiology rather than to psychology, must be assumed by the latter science as the basis of many of its researches. When the unpublished lectures of Sir W. Hamilton shall be given to the world, the English student of philosophy will have the means of seeing this question treated with the fulness and ability which its importance deserves.

But whether, in the widest sense of the term *consciousness*, it can or cannot be correctly described as prior to and independent of the act of attention, yet, in the narrower and more accurate sense, in which alone it can be the object of scientific analysis, attention becomes a necessary condition of its existence, or rather is identical with consciousness itself. Every phenomenon of consciousness proper, as before observed, must possess in some degree the attributes of *clearness* and *distinctness*, without which it can leave no trace in the memory, and cannot be compared with other phenomena of the same class. But to a clear or distinct consciousness it is necessary that an act of reflection should accompany the intuition; and to the act of reflection it is necessary that the phenomenon in question should have been observed with some degree of attention. The act of attention is therefore a necessary condition, possibly of the existence of a sensation in consciousness, but certainly of its recognition as such; and, in strict language, it would not be inaccurate to describe attention as consciousness in operation relatively to a definite object. This intimate union of the active with the passive functions of the human mind; this presence in every complete act of consciousness of a voluntary and personal factor—a permanent *self* in the midst of transitory modes,—exhibits man as in some degree the master of his own consciousness, and the author of the phenomena which it reveals to him. It is the exaggeration or exclusive consideration of this element which is the source of most of the extravagances of idealist metaphysics, as its neglect or suppression has given rise to most of the opposite extravagances of sensationalism.

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[1] *Active Powers*, Essay ii., chap. 3.

[2] *Elements of the Philosophy of the Human Mind*, part ii., chap. ii.

OF IMAGINATION, MEMORY, AND HOPE.

In the act of attention the mind selects certain prominent features of an object of intuition, which thus become fixed in the memory, and capable of reproduction when the object is no longer present. The reproductive imagination is thus the sequel of attention, forming the second link in the chain of connection between the intuitive and the reflective consciousness.[1] Hence, in a strictly methodical arrangement, the treatment of attention and imagination should be postponed till after the complete examination of the phenomena of intuition. But the prominence which, in the majority of treatises on the subject, has been given to the sensible relations of these two cognate acts, may furnish both an excuse for the consideration of them in the present place, and an opportunity of pointing out some of the chief defects which may be noticed in the ordinary treatment of them. "Imagination," says Dr Reid, "when it is distinguished from conception, seems to me to signify one species of conception—to wit, the conception of visible objects."[2] In this he follows the language of Descartes,—"Imaginari nihil aliud est quam rei corporeæ figuram seu imaginem contemplari."[3] Mr Stewart, though differing in his language, virtually limits the office of the same faculty to the reproduction of sensible impressions, though he does not, like the two authors last cited, confine it to the impressions of sight. Under the name of *conception*, he defines it as "that power of the mind which enables it to form a notion of an absent object of perception, or of a sensation which it has formerly felt."[4] Of the proper sense of the term *conception* we shall have occasion to speak hereafter. For the present, it will be sufficient to observe that imagination, in the proper psychological sense of the term, should not be confined to the reproduction of the phenomena connected with the bodily senses. It should rather be defined as "the consciousness of an image in the mind, resembling and representing an object of possible intuition. Not the objects of sense alone, but the presentations of intuition, external or internal, desires, affections, volitions, thoughts, as well as sounds, or colours, or figures, —everything, in short, that can be experienced in consciousness as an individual thing, act, or state of mind, may remain as an image in the memory, or be reproduced in the mind at a future period. Or the detached portions of objects once perceived may be combined by the imagination in a manner in which they have never been presented in any actual experience. Thus, when the upper parts of a man and the lower parts of a horse have been perceived by the sense in separate objects, the image of a centaur may be formed as readily as that of a horse or a man. It is to this last "power of modifying our conceptions, by combining the parts of different ones together, so as to form new wholes of our own creation," that Mr Stewart would confine the term *imagination*. The distinction really lies not so much in the image obtained as in the manner of obtaining it; and, though worthy of notice on many accounts, should, I think, be expressed in different language.

Imagination is of two kinds, which, following the plan of classifying the phenomena of mind by the leading characteristics of each, may be distinguished as belonging to the intuitive and the reflective consciousness respectively. The first, in which the mind is comparatively passive, consists in the continuance, in a weaker form, of a sensible or otherwise intuitive impression, when the object which gave rise to it is no longer present.[5] This is the imagination which is described by Aristotle as a *kind of weak sensation*,[6] and as *sensitive imagination*.[7] When coupled with a consciousness of the past existence of the impression which it represents, it forms the *memory*, as distinguished from the *reminiscence* of Aristotle.[8] The other kind of imagination is more properly an act of thought,[9] and consists in constructing in the mind an individual image (whether actually resembling a former impression or not) in accordance with the attributes contained in a given general notion. In this instance, imagination coincides with a faculty to be hereafter described,—*conception*. It is, in fact, individualizing the contents of a concept or general notion, so as to depict them (which in their general form is impossible) to the intuitive consciousness. This kind of imagination may be simpler or more complex, according as the image is constructed immediately, from the data furnished by the given notion, or mediately, from a train of associations which that notion suggests. It includes under it as a species the *deliberative imagination* of Aristotle; and, when coupled with the conscious effort to recal a past impression, corresponds in some degree to the *reminiscence* of the same philosopher.[10]

Imagination, memory, and hope are psychologically one and the same faculty.[11] In imagination, the presence of the image is necessarily accompanied by a conviction of the *possible* existence of the corresponding object in an intuition.

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[1] See Morell, *Elements of Psychology*, p. 169.

[2] *Intellectual Powers*, Essay iv., chap. 1.

[3] *Meditatio Secunda*. The office of imagination in relation to two other senses is accurately described in the lines of Shelley—

"Music, when soft voices die,
Vibrates in the memory;
Odours, when sweet violets sicken,
Live within the sense they quicken."

[4] *Elements of the Philosophy of the Human Mind*, part i., chap. iii.

[5] Arist. *Anal. Post.* ii. 19. Ἐνούσης δ᾽ αἰσθήσεως τοῖς μὲν τῶν ζώων ἐγγίνεται μονὴ αἰσθήματος, τοῖς δ᾽ οὐκ ἐγγίνεται. Ὅσοις μὲν οὖν μὴ ἐγγίνεται, ἢ ὅλως ἢ περὶ ἃ μὴ ἐγγίνεται, οὐκ ἔστι τούτοις γνῶσις ἔξω τοῦ αἰσθάνεσθαι· ἐν οἷς δ᾽, ἔνεστι [μὴ] αἰσθανομένοις ἔχειν ἔτι ἐν τῇ ψυχῇ. The negative inserted by Trendelenburg appears indispensable to the sense.

[6] *Rhet.* i. 11.

[7] *De Anima*, iii. 11. Η μὲν οὖν αἰσθητικὴ φαντασία καὶ ἐν τοῖς ἄλλοις ζῴοις ὑπάρχει, ἡ δὲ βουλευτικὴ ἐν τοῖς λογιστικοῖς.

[8] Aristotle, *De Memoria*, c. 1. Τίνος μὲν οὖν τῶν τῆς ψυχῆς ἐστὶν ἡ μνήμη; φανερόν, ὅτι καὶ οὗπερ ἡ φαντασία· καὶ ἔστι μνημονευτὰ καθ᾽ αὑτὰ μὲν ὅσα ἐστὶ φανταστά.

[9] *De Memoria*, c. 2, 25. Διαφέρει δὲ τοῦ μνημονεύειν τὸ ἀναμιμνήσκεσθαι, οὐ μόνον κατὰ τὸν χρόνον, ἀλλ᾽ ὅτι τοῦ μὲν μνημονεύειν καὶ τῶν ἄλλων ζῴων μετέχει πολλά, τοῦ δ᾽ ἀναμιμνήσκεσθαι οὐδὲν, ὡς εἰπεῖν, τῶν γνωριζομένων ζῴων πλὴν ἄνθρωπος. Αἴτιον δ᾽ ὅτι τὸ ἀναμιμνήσκεσθαί ἐστιν οἷον συλλόγισμός τις.

[10] By reminiscence, Aristotle means the process of endeavouring to reproduce something formerly in the memory, indirectly, by means of associated ideas. Memory proper comes in at the conclusion of the process, though it may also exist without it. (See *De Memoria*, ii. 4.) In this point of view, it is obvious that memory is the result of a process of thought, and therefore should not have been identified with that retention or remembrance which in the same chapter is described as common to men and brutes. It would be more accurate to distinguish between *intuitive* and *reflective* remembrance, according as it is performed without or with the intervention of a concept; and of the latter the Aristotelian ἀνάμνησις is a special form.

[11] See Sir W. Hamilton, *Discussions*, p. 52.

Memory is the presence of the same image, accompanied by a conviction of the fact that the object represented has actually existed in a *past* intuition. Hope, in like manner, is the presence of the same image, together with an anticipation, more or less vivid, of the actual existence of the object in a *future* intuition. Imagination, memory, and hope are thus (whether formed by a reflective process or not), in their actual results partly *presentative*, partly *representative*. They are presentative of the image, which has its own distinct existence in consciousness, irrespectively of its relation to the object which it is supposed to represent. They are representative of the object, which that image resembles, and which, either in its present form or in its several elements, must have been presented in a past act of intuition. Thus there is combined an immediate consciousness of the present with a mediate consciousness of the past. An immediate or presentative consciousness of the past or the future, as such, is impossible.

Imagination being representative of an intuition, is, like intuition, only possible on the condition that its immediate object should be an *individual*. If we try to form in our minds the image of a triangle, it must be of some individual figure,—equilateral, isosceles, or scalene. It is impossible that it should, at the same time, be all of these, or none. It may bear more or less resemblance to the object which it represents; but it can attain to resemblance at all only by being, like the object itself, individual. I may recall to mind, with more or less vividness, the features of an absent friend, as I may paint his portrait with more or less accuracy; but the likeness in neither case ceases to be the individual representation of an individual man. On the other hand, my *notion of a man in general* can attain to universality only by surrendering resemblance; it becomes the indifferent representative of all mankind, only because it has no special likeness to any one in particular. This distinction must be carefully borne in mind in comparing imagination with the cognate process of conception.

OF INTERNAL INTUITION IN GENERAL.

Locke, as is well known, referred the origin of our ideas to two sources,—*sensation*, by which we acquire our knowledge of external objects; and *reflection*, by which we become acquainted with the internal operations of our own minds. The latter term is unfortunately chosen, as it naturally suggests the notion of a *turning back* of the mind upon an object previously existing; and thus represents the phenomena of consciousness as distinct from the act of reflecting upon them. Understood in this sense, reflection can have no other objects than the phenomena of sensation in some one of its modes; for sensation and reflection are the only recognised sources of knowledge; and if reflection implies a previously existing operation of mind, that operation can be none other than sensation. Interpreting Locke in this sense, Condillac and his followers were only carrying out the doctrine to its legitimate consequences when they maintained that sensation was the only original source of ideas, and furnished the whole material of our knowledge. But though the language of Locke is both unfortunate in its choice of terms and vacillating in the use of them, the general tenor of his philosophy demands a different interpretation of the term *reflection*, as synonymous with *internal consciousness;* that is to say, as a knowledge of the presence of certain inward phenomena of mind, which exist only as they are known, and are known only as they exist. Reflection is thus an original and independent source of ideas, not distinct from, but identical with, the acts that are its objects. It is, in fact, the consciousness of those states of the mind by which it is placed in relation to itself, as sensation is the consciousness of those states of the mind by which it is placed in relation to the material world. Both sensation and reflection thus denote original states of consciousness, which exist only in so far as we are conscious of them. For example, *I see, and I am conscious that I see.* These two assertions, logically distinct, are really one and inseparable. Sight is a state of consciousness; and I see only in so far as I am conscious of seeing. Here, then, is one source of ideas,—the consciousness of certain affections of our bodily senses in relation to external objects. Whatever comes from this source is classed by Locke under the general head of *ideas of sensation.* But again: I am angry, and I am conscious that I am angry; I fear, and I am conscious that I fear; I will, and I am conscious that I will. Here, too, are acts which exist only in so far as we are conscious of them, and which point to another and a distinct source of ideas,—the consciousness, that is to say, of internal phenomena taking place in the mind itself. Whatever comes from this source is classed by Locke under the general head of *ideas of reflection.* It is in this sense that he describes reflection as a source of ideas which every man has wholly in himself, and which, "though it be not sense, as having nothing to do with external objects, yet it is very like it, and might properly enough be called *internal sense.*"[1] And thus, also, in another passage, he says, "I cannot but confess that *external and internal sensation* are the only passages that I can find of knowledge to the understanding."[2] We may thus, retaining the substance of Locke's teaching, though slightly altering his language, divide the presentative consciousness into two kinds:—1. External intuition, which embraces the various phenomena of sensation and perception, together with that knowledge of the attributes of matter which is obtained through the locomotive faculty; and, 2. Internal intuition, which includes all those modes of consciousness in which we become immediately cognisant of the various states of our own mind, as well as the concomitant consciousness of our own personality as the one permanent subject of these successive states. The phenomena of external intuition have been described in the preceding pages. We have next to consider those of internal intuition; and here it will be most convenient to begin with the variable element, as exhibited in the several mental states of which we are successively conscious. The form of this consciousness, as has been already observed, is *time.* The phenomena which we are about to describe constitute the matter.

OF THE CLASSIFICATION OF INTERNAL INTUITIONS.

Internal intuition, in the widest sense of the term, includes among its modes the whole of the phenomena of consciousness; for consciousness in general denotes a state of the mind; and all states of the mind are objects of internal intuition. In this extended signification, the phenomena of sensation and those of thought are both included under this head; for sensation, though in respect of its object it is external to the conscious mind, is in itself an affection of which that mind is intuitively conscious; and thought, in like manner, though in respect of its object it is mediate and representative, is in itself an individual act of which we are immediately and presentatively conscious. Thus, for example, *colour*, the object of sight, is an affection of the nervous organism, and therefore external to the immaterial self, the subject of consciousness; but *sight*, as a species of sensation, is a state of the personal consciousness, and, as such, internal. So, again, when I think of any material object, such as a tree or a stone, the object of which I think is external to the mind, and represented by the notion which I form of it; but the act of thinking about it is an individual affection of the conscious self, having its own definite position in time, and thereby numerically distinguished from every other affection, however similar. I may think of the same tree on twenty successive occasions; but my several thoughts, however identical in their objects, are nevertheless twenty successive, distinct, and individual states of my own mind, and, as such, belong to the class of internal intuitions. But in the practical treatment of the subject it is not necessary to take into consideration either of the above classes of mental phenomena; for the distinction between an act of consciousness and its object, though logically valid, has psychologically no existence. In no actual operation of consciousness can the act be separated from the object, or the object from the act. By no mental abstraction can either of these correlatives be conceived apart from the other,—though they are conceived together, not as identical, but as related and logically distinguishable. A perception cannot be conceived except as the perception of some object; an object of perception cannot be conceived except as in relation to a perceiving mind. In treating, therefore, of the phenomena of sensitive perception in relation to their external objects, we have at the same time sufficiently exhibited their internal character as acts of mind. A similar remark may be made with respect to the operations of thought. These will be examined hereafter in relation to the objects which they represent, and to their manner of representing them; and this examination will, at the same time, necessarily include their presentative aspect as individual phenomena of consciousness. The perceptive and discursive faculties, which are thus excluded from our present consideration, embrace all those operations of consciousness which are usually referred to the head of *cognitive* or *intellectual powers*. There will still remain for consideration the various phenomena which in the same division are classified, not very accurately, as belonging to the *appetitive* or *active powers*;[1] and which may, perhaps, be more exactly comprised under the three appellations of,—1. *Emotions* or *passions*; 2. *Moral judgments*; 3. *Volitions*.[2] It is difficult to fix upon any positive mark which shall express the distinctive characteristic of this group of mental phenomena, viewed as constituting a single class; though they may, perhaps, be sufficiently distinguished from other states of mind by the negative criterion of attributes which they do not possess. The internal intuitions, as a class, may, in this way, be described as comprehending all those affections of mind which are neither directly caused by conditions of the nervous organism nor representative of an object distinct from themselves. The first criterion will distinguish them from the sensitive affections; the second, from the intellectual powers properly so called. An instance will perhaps explain the distinction more clearly than a definition. A man may be affected with fear at the sight of a lion. The emotion of fear may in one sense be said to be caused by an affection of the optic nerve—the sight,—and to have an object distinct from itself—the lion; but it is neither the immediate and necessary consequence of the one, nor is it representative of the other. It is quite possible for the man to see the lion without fearing him; and it is quite possible that he should fear him if he suspected that he was concealed near him, without any sensible intimation of his presence. And though the lion is the ultimate object of the mental affection, both when we think of him and when we are afraid of him, yet he is not represented in the mind by our fear as he is by our thought. An emotion, or other internal intuition, may accompany an act either of perception or of thought, though it is perfectly distinguishable from the one and the other. The pleasure which we experience at the sight of a beautiful prospect, and the desire which we have to see it, are both distinct from the sight itself,—just as the liking for mathematical studies, and the gratification arising from the solution of a problem, are distinct from the demonstrative process itself.

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[1] *Essay*, b. ii., chap, i, sect. 4.

[2] *Essay*, b. ii., chap. xi., sect. 17.

OF THE PASSIONS OR EMOTIONS.

Perhaps the nearest approach to a positive definition of the passions or emotions may be found in the language of Aristotle, who describes them as *those states of mind which are accompanied by pleasure or pain*;[3] but the definition requires some explanation before it can be accepted as satisfactory. A toothache is accompanied by pain; but a toothache is not an emotion. The pursuit and acquisition of knowledge is a source of pleasure; but neither the pursuit nor the acquisition can be classed among the emotions. But it is necessary to distinguish between the bodily sensation or the mental energy, considered in itself, and the feeling of liking or disliking by which it is accompanied. The bodily sensation is not pleasant or painful *per se*, but may be the one or the other, according to the degree in which it exists. The sensation of heat, for example, up to a certain point, is the pleasant feeling of warmth; beyond that point, it is the painful feeling of burning. The sensation of touch may be pleasant or painful or indifferent, according to the nature of the body with which we are in contact, or the degree of resistance which it offers. Light, within certain limits, is pleasant to the eye; increased beyond those limits, it is dazzling and painful. The sensation itself is in no case an emotion: the feeling of liking or disliking, which accompanies it, is so. The essence of the bodily sensation consists in its being a nervous affection of a particular kind. The accident, or emotion which in certain cases accompanies it, is, that that particular affection is agreeable or disagreeable. The same may be said of the mental energies likewise. The *desire* of knowledge and the *pleasure* which it imparts are emotions: the act of pursuit and the state of possession are not so. It is perfectly conceivable that men might be so constituted as to seek after knowledge, from a rational conviction that it is their duty to do so, without deriving the slightest gratification from the pursuit or the acquisition; just as they might take food, from a conviction of the duty of preserving life, without being actuated either directly by the appetite of hunger, or indirectly by the love of life. Under this explanation, we may, with tolerable accuracy, define the emotions or passions as *those states of mind which consist in the consciousness of being affected agreeably or disagreeably*; and consistently with this point of view, an eminent modern philosopher has observed that there are, strictly speaking, but two passions,—the one arising from the consciousness of pleasure, manifesting itself in the successive stages of *joy, love*, and *desire*; the other arising from the consciousness of pain, and exhibiting the successive forms of *grief, hate*, and *aversion*.[1] The various subdivisions of these two classes are, properly, not so much distinctions in the nature of the emotion itself, as in that of the objects upon which it is exercised.

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[1] Of this classification Sir W. Hamilton observes:—"The division of the powers into those of the *understanding* and those of the *will* is very objectionable. It is taken from the peripatetic distinction of these into *gnostic* or *cognitive*, and *orectic* or *appetent*; but the original division is far preferable to the borrowed; for, in the first place, the term *understanding* usually and properly denotes only a part—the higher part—of the cognitive faculties, and is thus exclusive of sense, imagination, memory, &c., which it is now intended to include. In the second place, the term *will* is also usually and properly limited to our higher appetencies, or rational determinations, as opposed to our lower appetencies, or irrational desires, which last, however, it is here employed to comprehend. In the third place, both the original and borrowed divisions are improper, inasmuch as they either exclude or improperly include a third great class of mental phenomena—the phenomena of *feeling*. "The distribution of our powers into *speculative* and *active* is also very objectionable. Independently of the objection common to it with that into the powers of the understanding and the powers of the will—that the feel- ings are excluded or improperly included—it is liable to objections peculiar to itself. In the first place, *speculation* or theory is a certain kind or certain application of knowledge; therefore *speculation* is not a proper term by which to denote the cognitive operations in general. In the second place, *speculation* and *knowledge* are not opposed to *action*, but to *practice* or *doing*, or, as it is best expressed in German, *das Handeln*. *Speculative* powers ought not, therefore, to have been opposed to *active*. In the third place, the distinction of *active* powers is in itself vicious, because it does not distinguish, or distinguishes wrongly. *Active* is opposed to *inactive*; but it is not here intended to be said that the cognitive powers are inactive, but merely that the action of the powers of appetency is different in kind from the action of the powers of knowledge. The term *active* does not, therefore, express what was meant, or rather does express what was not meant. It is to be observed, however, that the English language is very deficient in terms requisite to denote the distinction in question." (*Reid's Works*, p. 511.) A somewhat similar criticism has been made by Brown, Lecture xvi., who uses the term *emotions* to denote the internal intuitions in general. For the classification approved by Sir W. Hamilton himself, see the next note.

[2] Sir W. Hamilton, in the advertisement to the second volume of *Stewart's Works*, observes that, "if we take the mental to the exclusion of material phenomena, that is, the phenomena manifested through the medium of self-consciousness or reflection, they naturally divide themselves into three categories or primary genera;—the phenomena of knowledge or cognition,—the phenomena of feeling, or of pleasure and pain,—and the phenomena of conation, or of will and desire." This division, which had previously been given by Kant in his *Kritik der Urtheilskraft*, though made on a somewhat different principle, coincides to a great extent with that given in the text. The phenomena of knowledge will include the external intuitions already treated of, together with the moral judgments and the operations of thought proper. The phenomena of feeling answer to the class of emotions, and those of conation in some degree to that of volitions. But in the present article the desires are classed with the feelings, and not, as in the above-mentioned arrangement, with the will.

[3] *Eth. Nic.* ii. 5. Λέγω δὲ πάθη μὲν ἐπιθυμίαν, ὀργήν, φόβον, θράσος, φθόνον, χαράν, φιλίαν, μῖσος, πόθον, ζῆλον, ἔλεον, ὅλως οἷς ἕπεται ἡδονὴ ἢ λύπη.

Hitherto we have used the words *passion* and *emotion* as synonymous. The above remarks will suggest, in stricter language, a distinction between them, which, though by no means accurately observed either in philosophical writings or in popular use, is yet in many cases imperfectly intimated by both. To distinguish, indeed, between these terms, in strict accordance either with philosophical or general usage, is out of the question; for scarcely any two writers or speakers are in all respects consistent with each other. Sometimes emotion is a species of passion; sometimes passion is a species of emotion; sometimes the two terms are used as exactly synonymous; and at others the word *passion* is used to designate a violent degree of emotion. A more serviceable, and therefore a better, distinction than any of these may, we think, be furnished by the characteristics of the phenomena themselves,—a distinction which, though not warranted by the etymology of the two words, yet appears to express with tolerable accuracy the difference imperfectly intimated in their popular use. Our internal as well as our external intuitions have both a subjective and an objective phase, inseparable from each other, but logically distinguishable. This distinction, which in the case of our external intuitions is expressed by the terms *sensation* and *perception*, may be marked in its internal aspect by the corresponding usage of *emotion* and *passion*. The mental phenomena of this class are composed of two principal ingredients,—a consciousness of being affected agreeably or disagreeably by a certain object, and a desire to obtain or avoid, to advance or impede, the object thus affecting us. This is equally the case, whether the object affecting us be a physical good, as in the feeling of hunger; a mental enjoyment, as in the desire of honour or knowledge; or the welfare of another, as in the benevolent affections. In all alike we may trace the fundamental distinction of consciousness, the distinction between myself affected and the object affecting me, whether that object be regarded as a reality separate from myself or not. The subjective feeling of pleasure or pain may, we think, be appropriately expressed by the term *emotion*; while the objective tendency to the thing by which that emotion is caused may be indicated, not improperly, by the term *passion*, which, in its ordinary signification, appears to denote those particular propensities of our nature which, in the language of Bishop Butler, have for their objects "external things themselves, distinct from the pleasure arising from them."[2] The passions, as thus described, may be excited by an object either perceived as present, or imagined as absent; the object being in the one case presented, in the other represented. When this representation is accompanied by a conviction of the possibility or impossibility of obtaining the object, the passion assumes the form of *hope* or *despair*,—terms which, in their widest sense, do not denote special passions, but general relations in which any particular passion may stand towards its own object. But the passion, as actually existing, whether directed towards a present or an absent object, is in every case an individual state of mind, intuitively discerned as now present in consciousness.[3]

The further subdivisions of the passions may be made on various principles, and from various points of view. The general features which have been above described as characteristic of this class of mental phenomena will, in their special manifestations, be subject to various modifications, according to the nature of the object upon which they are exercised, or the constitution and training of the subject in whom they exist. To attempt a complete enumeration of the complex modes of consciousness thus arising would be impossible: we must content ourselves with selecting some one principle of division, and pointing out a few of the most important and universal of the feelings comprehended under it. Perhaps, on the whole, the least objectionable principle of classification is that derived from the various classes of objects in relation to which the emotions of pleasure and pain, and the corresponding feelings of attraction or repulsion which constitute passion, may take place. In this point of view the passions may be divided, generally, into the two classes of *desires* and *affections*, according as the object to which they are related is a *thing* or a *person*,—regarded as a possession to be sought for or avoided, or as a moral agent, capable of mutual relations of sympathy or antipathy. Under the general head of desires may be specified the *appetites*, which take their rise from bodily conditions, and are common to men and brutes,—comprising the feelings of hunger, thirst, and sexual instinct; and the *desires*, as they are sometimes called in a special sense, such as the desire of knowledge, of society, of esteem, of power, and of superiority, together with the counter feelings of repugnance to the opposite class of objects.[4] The affections embrace our social, domestic, and religious feelings in general; the love of friends, of kindred, of God, and the special modifications of feeling arising from our particular relations with individuals among our fellow-men; such as respect, gratitude, compassion, anger, contempt, and so forth. The principles of self-love and benevolence, which are sometimes included in this enumeration, should be considered, not as original intuitions, but rather as derived conceptions, in which the several personal or social passions and their respective objects, together with their moral relations and observed consequences, are generalized into the comprehensive notions of a *regard for the welfare* of ourselves or of others.

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[1] Jouffroy, *Mélanges Philosophiques*, p. 269. Cf. Damiron, *Psychologie*, vol. i., p. 247.

[2] Sermon xi., "On the love of our neighbour."

[3] Aristotle, *Rhet.* i. 11. *Ανάγκη πάντα τὰ ἡδέα ἢ ἐν τῷ αἰσθάνεσθαι εἶναι παρόντα, ἢ ἐν τῷ μεμνῆσθαι γεγενημένα, ἢ ἐν τῷ ἐλπίζειν μέλλοντα· αἰσθάνονται γὰρ τὰ παρόντα, μέμνηνται δὲ τὰ γεγενημένα, ἐλπίζουσι δὲ τὰ μέλλοντα.*

[4] For the details of this classification, see Stewart's *Philosophy of the Active and Moral Powers.*

The complete treatment of the emotions and passions belongs to the province of moral philosophy. To the metaphysician they are important, chiefly in two points of view, *psychologically*, as individual phenomena of consciousness, perceived intuitively, and therefore capable of being conceived reflectively; and *ontologically*, as regards the light which they may be able to throw on the problem of the real existence of the subject or object to which they are related. In this latter point of view they will come again under our notice hereafter.

OF THE MORAL FACULTY.

Every passion, as we have seen, is ultimately related to an object regarded as the cause of agreeable or disagreeable emotions. But between the passion and its object there is always an intervening medium of communication,—the *action* by which the object is to be obtained or avoided. Pleasure and pain, so far as they are the objects of desire and aversion, do not properly lie in the things by which they are caused, but in the actions by which those things are brought into contact with the person affected. But the actions, and in some degree also the feelings which prompt them, may be exhibited in another point of view, not merely as pleasant or painful, but as *right* or *wrong*. The existence of these terms, or their equivalents, in every language, indicates a corresponding phenomenon in the universal consciousness of mankind, which no effort of ingenuity can explain away. Indeed, the very ingenuity of the various attempts that have been made to identify the conception of *right* with that of *expedient*, or *agreeable*, or any other quality, is itself a witness against them; for no such elaborate reasoning would be required, were it not necessary to silence or pervert the instinctive testimony of a too stubborn consciousness. That the terms *right* and *wrong* indicate a special class of mental phenomena, discernible in the contemplation of actions in themselves, and not merely inferred from observation of their consequences, is a truth guaranteed by the universal language of mankind, by the testimony of every man's own consciousness, and by the inconsistencies and mutual contradictions of its several antagonists. But what are these phenomena, and by what means are they discerned? Are they qualities of actions in themselves, or states of the mind which contemplates actions? Are they simple qualities, or complex; perceived intuitively, or conceived reflectively? Are they the objects of a special mental faculty, or are they discerned by the same faculty which perceives truth and falsehood in other cases? These doubts may be summed up, in the language of Stewart, in the two following questions, which, as he says, seem to exhaust the whole theory of morals:—"First, by what principle of our constitution are we led to form the notion of moral distinctions,—whether by that faculty which perceives the distinction between truth and falsehood in the other branches of human knowledge, or by a peculiar power of perception (called by some the moral sense) which is *pleased* with one set of qualities and *displeased* with another? Secondly, what is the proper object of moral approbation; or, in other words, what is the common quality or qualities belonging to all the different modes of virtue? Is it benevolence, or a rational self-love, or a disposition (resulting from the ascendant of reason over passion) to act suitably to the different relations in which we are placed?"[1]

The two alternatives proposed in the first of the above questions represent the antagonist views of the two schools of philosophy which made common cause with each other in protesting against the denial of all natural right and wrong, which characterized the philosophy of Hobbes. The first represents the opinion of Cudworth and his followers, who refer our knowledge of right and wrong to a decision of the *reason* or *understanding*. The second is the opinion of Hutcheson and those who with him maintain the existence of a faculty of *moral perception* or *sense*. The language in which the two theories are worded, though historically accurate, as representing the views of their respective authors, is in some degree defective in philosophical precision. On the one hand, there is no single faculty of mind which distinguishes between truth and falsehood in the various branches of knowledge. The understanding or reason, taken in its widest sense, to denote the reflective faculty in general, contributes only one element to the decision. Truth and falsehood depend upon the agreement or disagreement between the representations which we make of an object in thought, and the qualities presented by that object in intuition; and this agreement or disagreement can only be ascertained by the co-operation of the two faculties. How, for instance, do we know that it is true to conceive snow as white, and false to conceive it as black? The understanding furnishes the conception; but has the sight, therefore, nothing to do with the decision? Could we answer the question by the mere act of thought, without reference to the perception of a present, or the recollection of a past fact of intuition? If there were no moral intuition, truth and falsehood could have no place in moral thought; for the conception of right or wrong, even supposing that it could exist, would be related to no facts with which it could agree or disagree. Moral truth and falsehood, like all other truth and falsehood, must consist in the agreement or disagreement of thoughts with facts; and this may take place in two different ways, as regards the mental phenomenon or the extra-mental reality. For example: I may, owing to an inaptitude for mental analysis, have an inaccurate conception of the characteristics of a moral judgment which I have myself exercised. Hence will result a false representation of the phenomenon of moral approbation. Or I may have conceptions of right and wrong, perfectly in accordance with the facts of my own consciousness, but at variance with some higher standard of right and wrong *per se*. The latter is an ontological falsehood, the criterion of which we are not yet in a position to determine. The former is a psychological falsehood, which can only be corrected by comparing the thought with the intuition to which it is related. But in neither case can the act of thought guarantee its own accuracy; else would every conception be equally true, for the sole reason that it is conceived. On the other hand, Hutcheson and his followers, as Stewart has observed, while rightly admitting the existence of a moral intuitive faculty (whether it be called *sense* or not is unimportant), unfortunately, in their description of its operation, were too much misled by a false analogy derived from the perception by the bodily senses of the secondary qualities of matter. It is no necessary part of the theory of a moral sense that it should be represented as perceiving qualities only in so far as they are *pleasing* or *displeasing*. It is true that the exercise of our bodily senses produces pleasure as well as information; but the perception of a fact is logically distinguishable from the sensation of an affection; and, however much in practice they may be united, either may be conceived to exist independently of the other. If, in like manner, we distinguish between the *moral perception* of an act as right or wrong, and the accompanying *moral sensation* of the pleasing or displeasing manner in which we are affected by those qualities, the hypothesis of a moral sense may be freed from most of the excrescences which have hitherto disfigured it in the systems of its advocates, and have afforded the chief handle to the criticisms of its antagonists.

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[1] *Philosophy of the Active and Moral Powers*, b. ii., chap. v.

An illustrious critic of this hypothesis[1] has remarked with truth, that in our perception of the moral character of an act, whether done by ourselves or by others, we may trace the united action of a *moral judgment* and a *moral sentiment.* Our *feeling of indignation* at an act of treachery may be more or less vivid, according to our proximity to the time and place at which the act was committed, or to our relation to the doer or the sufferer. Our *condemnatory judgment* is independent of the accidents of time, place, or circumstance; we pronounce the action to be evil with the same assurance, whether it was done yesterday, or ten years, or a thousand years ago; whether the victim was our dearest friend or a complete stranger. Of these two elements of moral consciousness, the judgment is the superior, the permanent, the essential factor; the sentiment is the inferior, the fluctuating, the accidental one. The sentiment, he adds, may be due to a moral sense; but the judgment, which is derived from the universal and necessary ideas of good and evil, can belong to no other faculty than the reason.

The above analysis, though true so far as it goes, is, like that which it criticises, incomplete. The moral judgment itself may be further divided into two constituent parts; the one, an individual fact, present now and here; the other, a general law, valid always and everywhere. That this particular act of my own, at the moment of being committed, is wrong, is a fact presented immediately by the judgment of conscience. That all acts of the same kind, whensoever or by whomsoever committed, are necessarily wrong, is a judgment formed by the reason through the medium of the general notions of acts of a certain class, and of right and wrong. The latter, as an universal and necessary truth, may be referred to the same faculty, and formed under the same conditions, as other truths of the same kind. The former, as the *presentative condition of moral thought*, must be allowed to possess that chronological priority which in other cases is admitted to exist in individual facts, as compared with universal notions.

A more accurate theory of the nature and origin of moral judgment than is contained either in the moral reason of Cudworth, or in the moral sense of Hutcheson, or even in M. Cousin's union of the two, may, we think, be proposed in accordance with what has been said in the preceding pages of the complex nature of consciousness in general. It has been before observed, that every mode of consciousness, to be known as such, must possess a certain degree of clearness and distinctness, and that this is the product of the combined action of the presentative and representative faculties. The distinctions of language are doing their work; the task of education is going on; the phenomena of consciousness are assuming shape and consistency, before we are capable of discerning the various transitory conditions of our minds, or of distinguishing them one from another. A conscious act of pure moral sense, like a conscious act of pure physical sense, if it ever takes place at all, takes place at a period of which we have no remembrance, and of which we can give no account. To have a clear notion of moral obligation as such, we must have reflected upon it; and to reflect upon it, we must have obscurely experienced various acts in relation to it, and others distinct from it. At what time the notions of *good, bad,* and *indifferent,* first clearly presented themselves to the mind, it is as impossible to say, as it is to determine when we first distinctly recognised as such, and severed from each other, the visible phenomena of *white, black,* and *grey.* All that we can hope to do is, by subsequent analysis of the compound phenomenon, to detect in its composition an intuitive and a reflective element, growing by side from the first dawn of intelligence, and contributing their respective shares to the gradual development of their mutual product. Our mental, no less than our bodily constitution, testifies that we are the work of One whose judgments are unsearchable and his ways past finding out. The results alone we know; the creative process we can but darkly conjecture. "As thou knowest not what is the way of the spirit, nor how the bones do grow in the womb of her that is with child; even so, thou knowest not the works of God who maketh all."

The preceding remarks have in some degree furnished by anticipation the answer to an objection which a distinguished author has recently urged against the theory of a moral sense as usually understood. "The judgment of man," it has been said, "concerning actions as good or bad cannot be expressed or formed without reference to language, to social relations, to acknowledged rights; and the apprehension of these implies the agency of the understanding in a manner quite different from the perceptions of the bodily senses."[2] If there is any truth in the view which has been taken, in the preceding pages, of the operations of the bodily senses, it appears that the perceptions of these also are not so independent of the agency of the understanding as is usually supposed; and that there is at least sufficient analogy between our physical and moral intuitions to justify the metaphorical use of the term *sense,* to denote the mode of action of the latter. But there still remains a point in which the ordinary theory needs correction. It is commonly said, that by the operation of the moral sense we perceive immediately the character of acts, whether done by ourselves or by others. The assertion that we are immediately conscious of the morality of another person's actions, appears to be an error of the same kind in relation to our moral perceptions, as the assertion that we are immediately conscious of the past in memory is in relation to our bodily senses. To be directly conscious that this act, now being committed, or about to be committed, is right or wrong, I must be directly conscious of two things: of a law of obligation, commanding a certain person to act in a certain way, and of the course now before that person, as agreeing or disagreeing with such law. But I cannot be directly conscious of a law of obligation as it exists in another person's mind: I can only infer its existence by *representing* his mind as similarly constituted to my own. If man were not a free agent, his acts, whether beneficial or hurtful in their physical results, could have no moral character as right or wrong. But I cannot be immediately conscious of the free agency of any other person than myself; and, were it not for the direct testimony of my own consciousness to my own freedom, I could regard human actions only as necessary links in the endless chain of phenomenal cause and effect. It is obvious, therefore, that the intuitive perception of moral qualities cannot extend beyond our own actions, in which alone we are directly conscious of a law of obligation and of a voluntary obedience or disobedience to it. The actions of other men may be known presentatively in their material aspect as beneficial or hurtful; for this is a relation external to the mind of the agent. They cannot be presentatively known in their moral aspect as good or evil; for this is an internal relation, existing in the hidden depths of another's consciousness.

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[1] M. Cousin. See his review of Hutcheson's system. *Cours de* 1819, Leçon 14.

[2] Whewell, Preface to Butler's Three Sermons.

The substance of the above remarks may be briefly summed up as follows:—Moral consciousness, in the only form in which it can be distinctly recognised in the mind, consists, like all other consciousness, of a presentative and a representative element; the one being necessary to its first formation, the other to its completeness and recognition as what it is. Neither reason alone, nor sense alone, can account for the existence of the moral judgment as a fact of consciousness, whether we regard it in its subjective aspect, as an emotion, pleasant or painful, analogous to sensation proper, or in its objective aspect, analogous to perception proper, as exhibiting a voluntary act in relation to a law. The presentative element must be referred to a special faculty of moral intuition or sense,—in one word, to avoid more objectionable phrases, to *conscience*,—whose object, like that of all intuitions, is an individual phenomenon now present:—a special faculty, we say, in the only point of view in which the mind can be said to have distinct faculties at all, namely, on the ground of a difference of which we are conscious in the corresponding objects. The representative element, on the other hand, in common with all other general notions, may be referred to the single faculty of the *understanding*.

Up to this point the moral problem is properly psychological; its purpose being only to determine what are the characteristic features and origin of the moral judgment, regarded as a fact of consciousness. The second question which Stewart proposes as completing the theory of morals,—"What is the proper object of moral approbation? or what is the common quality or qualities belonging to the different modes of virtue?"—is one which belongs not to psychology, but to moral philosophy, which, in this point of view, may be considered as a branch of ontology; its office being to inquire into the nature of virtue, regarded, not as a mental perception, but as an extra-mental reality. The moral decisions of conscience cannot by themselves be the ultimate criterion of right and wrong; for if so, whose conscience is to be taken as the standard? If the individual conscience is ever mistaken in its judgments; if crimes can ever be committed which seem no crimes to the perpetrator, there must be a standard of right and wrong *per se*, by which our moral intuitions and our moral conceptions must both, in ultimate appeal, be tested. To ask what this standard is, though the most important of all questions in speculative morals, would be out of place here; the only legitimate office of the psychological inquirer being to analyse and exhibit the characteristic features of the mental phenomenon of moral approbation.

OF VOLITION.

The correlative terms, *will* and *volition*, are usually distinguished, in the language of philosophy, as applying, the one to the general faculty, the other to the special acts in which it manifests itself. A volition is an act of the will; and our several volitions are classified as proceeding from one and the same faculty. *Will*, then, like *sense* and *reason*, does not indicate a special phenomenon of consciousness; but is a general name for the power from which special phenomena proceed, and which itself exists in consciousness only as it is manifested in operation. The examination, therefore, of this portion of our consciousness must be attempted in relation to the internal acts, which, in the usual language of philosophy, are denominated *volitions*.

That volition is not identical with desire, and cannot properly be classed with the phenomena of emotion, was one of the earliest results of psychological analysis, and is, indeed, obvious to the consciousness of every man who has experienced the two, however much they may have been confounded together by the perversity of a few unscrupulous system-makers. A man may be thirsty, and yet refuse to drink; his desire drawing him one way, and his will determining him in the other.[1] Desires are not under our own control; they arise naturally and necessarily on the occasion of the presence of objects which affect us agreeably or disagreeably. We cannot help being so constituted as to derive pleasure from certain objects; we cannot help feeling attracted to pleasant objects, for the pleasure constitutes the attraction. But we can help yielding to the attraction of desire when felt; and we can help putting ourselves in the way of feeling it. Desire may be vicious as well as action; but only in so far as either is combined with volition. I may place myself in the way of desirable objects, and, in so doing, my act is voluntary. I may give my attention to thoughts calculated to excite desire, and the attention is a voluntary act; but in the mere fact that an object, when present, no matter how its presence is procured, raises a corresponding emotion in the mind, there is no volition, and consequently no moral character. Hence it has long been established as a canon in morals by the soundest writers on the question, that virtue and vice depend, not in the existence of desires, but on their relation to the will.[2]

But volition must be further distinguished, both from the judgment which precedes, and from the external act which follows it.[3] For example, a man determines to take a walk for the benefit of his health. The feeling that health is desirable is not voluntary: the conviction that walking is beneficial to health is not voluntary. The one is an emotion, which by his constitution he cannot help having: the other is a relation between natural cause and effect, which he cannot make other than it is, and cannot judge to be other than he knows it to be. But, while conscious that health is desirable, and while conscious that walking promotes health, he is also (and this forms a distinct phenomenon) conscious that it is in his own power to take or not to take the means necessary to the end. We cannot at present inquire how far this consciousness of power answers to any corresponding reality in the nature of things. We are not yet in a condition to examine the paradox maintained by some philosophers, that consciousness deludes us with a fallacious appearance of liberty. We are concerned only with the mental phenomenon that a man does, in certain states of consciousness, feel possessed of a power of choosing between two alternatives, which in certain other states he does not feel. But again: Suppose that the man determines to walk, but finds himself, by a sudden stroke of paralysis, deprived of the use of his limbs: here again we must distinguish between the fact of determination, which is always in our own power, and the fact of bodily motion, which may or may not be in our own power, according to circumstances. The power of locomotion (I do not now speak of that of muscular effort) is not, properly speaking, a fact of consciousness at all; that is to say, it is not a fact whose existence is identical with our knowledge of its existence. We may suppose the case of a man whose limbs have become paralysed without his being aware of it. The conscious portion of the effort to move is the same as before, but the physical sequence is interrupted. Or we may suppose the act of motion to take place as a consequence of volition, without the person being conscious of the relation between the volition and the act. The latter supposition, indeed, is actually true in all cases; for motion is the remote, not the immediate, consequence of volition; and between the one and the other there is an intervening nervous and muscular action, of which we not only are not conscious in the act of moving, but which we may pass a whole lifetime without discovering.

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[1] Plato, *Republic*, b. iv., p. 439. Cf. Aristotle, *Eth. Nic.*, B. iii., c. 2. Προαιρέσει μὲν ἐπιθυμία ἐναντιοῦται, ἐπιθυμίᾳ δ' ἐπιθυμία οὔ.

[2] See especially Bishop Butler, *Sermons* i., ii., v., xi.; *Analogy*, chaps. iv., v.

[3] Cousin, *Cours de* 1819, Leçon xxiii. *Cours de* 1829, Leçon xxv.

Some philosophers of no small eminence, especially in this country, have maintained that we are not directly conscious of mind or self, but only of its several modifications.[1] It is in relation to the phenomena of volition that the error of this theory is most manifest. If, in the mental state which corresponds to the judgment, *I will*, there is no consciousness of *I*, but only of *will*, it is impossible to place the essential feature of volition, as has been done above, in *the consciousness of myself having power over my own determinations*. *Will*, and not *I*, being the primary fact of consciousness, the causative power of volition must be sought in the relation between will and some subsequent phenomenon; and so sought, it will assuredly never be found.[2] It cannot be found where Locke sought it,—in the relation between the determination of the will and the consequent motion of the limb; for the determination is not the immediate antecedent of the motion, but only of the intervening nervous and muscular action. I cannot, therefore, be immediately conscious of my power to move a limb, when I am not immediately conscious of my power to produce the antecedent phenomena. Nor yet can the causative power be found where Maine de Biran sought it,—in the relation of the will to the action of the nerves and muscles; for this relation may at any time be interrupted by purely physical causes, such as a stroke of paralysis; and in that case no exertion of the will can produce the desired effect. We can escape from this difficulty—the stronghold of scepticism and necessitarianism—by one path only, and that is by a more accurate analysis of the purely mental state, which will discover an immediate consciousness of power in *myself determining my own volitions.*

The essential characteristic of volition, as presented to the mind, consists in *the consciousness of a power of choosing between two alternative determinations*. But, by a natural association, as in the case of the acquired perceptions, we are led to connect the volition with its most striking, not with its most immediate consequence, and thus to believe that we have an immediate consciousness of our power to move the limbs of the body. The latter act is indeed voluntary, as being the foreseen, though remote, consequence of a volition; the remoteness of the consequence not affecting the moral responsibility; just as a man who shoots another is guilty of murder, though his immediate act is not to inflict the wound, but to pull the trigger. But the connection between volition and its remote consequences is not *presented* in consciousness, but *inferred*. The importance of the will as an element of consciousness, and its influence upon the other phenomena, may be in some degree estimated by comparing the characteristics of consciousness in its ordinary state with those which it presents during a *dream*. In the latter state the functions of volition, properly so called, are altogether suspended.[3] We may seem to ourselves to act as well as to suffer; but the action is not accompanied by a consciousness, at the moment of its performance, of a power to act otherwise. In other words, our actions during a dream are *spontaneous*, but not *voluntary*, being never presented to the consciousness in the form of a choice between two alternatives. Hence our inability during sleep to break off or change the direction of the train of ideas which is passing through the mind. Hence, too, the absence of all power of reflecting upon those ideas; and the natural consequence, that fancies the most absurd, and events the most improbable, are never at the time discerned as being so. It is impossible to compare the events of a dream with the natural course of things; for to do so we must make a voluntary effort to recal the latter to mind;—we must will to withdraw our attention from the phenomenon before us, and to fix it upon the remembrance of our past experience. It may be conjectured, with all the probability of which conjectures on such points are susceptible, that if man were, as so many philosophers have maintained, a necessary agent, determined even in his volitions by antecedent phenomena, his waking state would resemble that of a dream: he would be astonished at nothing. Astonishment, as Plato and Aristotle have said, is the commencement of philosophy.[4] When we examine, compare, judge, and pronounce sentence upon the phenomena of our own consciousness, we assert our right to a place distinct from, and superior to, that of a mere link in the chain of phenomena; we exercise the privilege of our conscious existence as beings above phenomena; though the being and the phenomenon are manifested together as parts of one and the same complex act of consciousness.

We may notice, in conclusion, the light that is thrown, by the phenomena of dreaming, on some of those remarkable cases of passive subjection to another person, which, under the names of Mesmerism, Hypnotism, or Electro-Biology, have of late years excited so much public attention, and given rise to such strange and unfounded theories of physical or hyperphysical agency. These states exhibit, in their ordinary features, little more than the mental phenomena of sleep without the accompanying bodily conditions. The mental phenomena of sleep exhibit two principal characteristics:—1. They show the power of the mind to produce, by its internal agency, sensible phenomena, having all the vividness and apparent reality of those communicated by impressions from without. 2. They show that the mind, under certain circumstances, may be so completely under the influence of a leading idea as to follow passively the train of associations suggested, without the slightest power of judging of their truth or falsehood, probability or absurdity. The principal difference between these phenomena and those of the above-mentioned states consists in the circumstance that the leading suggestion is, in the latter case, conveyed from without, by the operator, instead of from within, by the patient's own mind. Is there any necessary law of connection between the mental state of

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[1] Locke, *Essay*, b. ii., chap. xxiii., sect. 3, 5. Hume, *Treatise of Human Nature*, p. iv., sect. 5, 6. Reid, *Intellectual Powers*, Essay v., chap. ii. Stewart, *Elements*, Introduction, part i. See the next section on the Consciousness of Personality.

[2] Cousin, *Fragments Philosophiques*, Preface de la prémière edition.

[3] Stewart, in one of the most interesting chapters of his *Elements of the Philosophy of the Human Mind*, argues that the power of volition itself is not suspended during sleep, but only the influence of the will over the thoughts and actions. But he has not sufficiently distinguished between merely *spontaneous* acts and those which may properly be called *voluntary*. We are conscious in a dream of making an effort; but we are not conscious at the moment that it is in our power not to make it. Thus, though the active function of the mind is retained, the essential feature of volition has disappeared. This remark, however, applies only to the conscious exercise of volition in determining our own mental states. It is probable that spontaneity itself is but a lower form of volition; and attention, in which some amount of volition is always implied, seems to be a necessary condition of all consciousness, sleeping or waking. At any rate, it is necessary to recollection; and thus the phenomena of dreaming would, without some co-operation of the voluntary energy, either not take place at all, or be to the waking man as though they had never been.

[4] *Theætetus*, p. 155. *Metaph.* i. 2, 9.

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suspended volition and the bodily state of suspended susceptibility to external impressions? If, by any artificial means, the former of these states can be produced without the latter (and this is partially the case, even without artifice, in reverie and absence of mind), we have a link to connect these psychological marvels with the most familiar facts of our everyday experience.[1]

OF THE CONSCIOUSNESS OF PERSONALITY.

The universal language of mankind has established a distinction between the capacities of mind and matter, which philosophy has often, but in vain, attempted to explain away. We speak of the *properties* of material agents, of the *faculties* of the human mind.[2] It is a *property* of fire to burn, of metals to conduct electricity, of a tree to bear fruit after its kind. Sensibility, memory, reason, are *faculties* of the mind. Yet the attributes of mind, as well as those of body, are known only by their effects. I know that I have a power of thinking, only because I actually think,—as I know that fire is capable of burning, only because it actually burns. What, then, is the distinction between the nature of intelligent and unintelligent beings, to the existence of which our language instinctively bears witness? The foundation of the distinction is to be found in the *consciousness of self*. Whatever variety of phenomena may succeed one another within the field of consciousness, in all alike I am directly conscious of the existence of one and the same indivisible self, the centre and the possessor of each and all. Let system-makers say what they will, the unsophisticated sense of mankind refuses to acknowledge that mind is but a bundle of states of consciousness, as matter is (possibly) a bundle of sensible qualities. There may be no material substratum distinct from the attributes of extension, figure, colour, hardness, &c. Matter may be merely a name for the aggregate of these, for we have no immediate consciousness of anything beyond them; but, unless our whole consciousness is a delusion and a lie, *self* is something more than the aggregate of sensations, thoughts, volitions, &c. Our whole consciousness is manifested as a relation between a permanent and a changeable element,—a conscious self, affected in various manners. The notion of a state of consciousness, with no one to be conscious of it, is as absurd as the opposite fiction of a conscious self with nothing to be conscious of. If the latter has given rise to the extravagances of rational psychology, the former is the basis of a not less extravagant reaction, which in its logical consequences leads to the consistent denial of personality, of freedom, of responsibility; nay, of the very conceptions of substance and cause, the foundations of all philosophy.

Consciousness is given to us as a relation; and no effort of analysis can separate the two correlatives; for analysis is itself an act of consciousness, and contains the same relation. We cannot conceive either factor of consciousness apart from the other; but, on the other hand, we cannot annihilate either in conceiving their product. We cannot analyse the judgment *I will*, and set an abstract *I* on the one side, and an abstract *will* on the other; but neither can we conceive the entire judgment, save as the product of two constituent elements. Whatever may be the variety of phenomena of consciousness,—sensations, volitions, thoughts, imaginations,—of all we are immediately conscious as affections of one and the same self. It is not by any subsequent effort of reflection that I combine together sight and hearing, thought and volition, into a factitious unity or compounded whole: in each case I am immediately conscious of *myself* seeing and hearing, thinking and willing. This personality, like all other simple and immediate presentations, is indefinable; but it is so because it is superior to definition. It can be analysed into no simpler elements; for it is itself one element of a product which defies analysis. It can be made no clearer by description or comparison; for it is revealed to us in all the clearness of an original intuition, of which description and comparison can furnish only faint and partial resemblances.

Relation is the law of consciousness, and relation is the end of philosophy; for philosophy is only the articulate expression of consciousness. *Cogito, ergo sum*, may indicate a legitimate passage from thought to being, from psychology to ontology; but the thought and the being alike are manifested only in the form of relation. Whether that dualism, which in another country has become a byeword for unphilosophical thinking, may be made the basis of a sounder philosophy than the mutilated and shapeless fragment which aspires to the name of unity, is a question which is probably reserved for a future generation to answer. This much, however, appears to be proved by experience as well as testified by reason, that it is hopeless to attempt to found philosophy on the annihilation of consciousness.

We have now described the principal phenomena of the intuitive consciousness, in which are presented to us individual states of the mind in relation either to itself or to the material world. We have next to describe the phenomena of the reflective consciousness, in which the several intuitions, external or internal, are represented under general notions, and thus become objects of thought.

OF REPRESENTATIVE OR REFLECTIVE CONSCIOUSNESS.

The term *representation* has been used by philosophers in various senses. In the Leibnitzian and subsequent philosophies of Germany, this word, or its German equivalent *Vorstellung*,[3] is employed to denote any cognitive act, including even those obscure cognitions, as they are termed by Leibnitz, which do not amount to a conscious apprehension of an object as such. Thus Kant includes under the common genus of *representation* the successive subclasses of representation with consciousness, or *perception;* which is divided into subjective perception, or *sensation*, and objective perception, or *cognition;* the latter containing under it immediate cognition, or *intuition*, and mediate cognition, or *conception*.[4] On the other hand, Sir William Hamilton, distinguishing between *presentative* and *representative knowledge*, and rightly referring the perceptions of the senses to the former class, uses the term *representation* to denote exclusively the cognition of individual objects by means of images resembling them.[5] Representation, thus distinguished, is synonymous with imagination, and does not include the operations of thought properly so called, which have for their immediate object general notions or concepts. In the present article it has been found convenient to adopt an intermediate course. Kant's extension of the term *representation*, to include the intuitions of sense, involves, even on his own theory of sensitive perception, at least an unnecessary ambiguity of language. The intuition, on that theory, is representative of nothing that can possibly come within the sphere of consciousness, but of an unknown and unknowable *thing in itself*, or absolute reality out of all relation to human faculties. Concepts, on the contrary, are representative of intuitions, from which they are originally derived, and whose place they

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[1] See Sir Henry Holland's *Chapters on Mental Physiology*, chap. ii., v.; Carpenter's *Principles of Human Physiology*, p. 859.; *Quarterly Review*, No. 186.

[2] Jouffroy, *Mélanges Philosophiques*, p. 312.

[3] Etymologically, the term *Vorstellung* means presentation rather than representation; but in its actual use in philosophy it is generally equivalent to the latter.

[4] *Kritik der reinen Vernunft*, Transc. Dial., B. i., Abschn. 1.

[5] *Reid's Works*, p. 805, 809. *Discussions*, p. 13.

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occupy in the processes of thought. But it is obvious that, in the analysis of consciousness, the thing in itself, being *ex hypothesi* unknown and unknowable, may be dropped out of our reckoning altogether. The intuition, or consciousness of an individual object, being the commencement of our knowledge and the point beyond which it cannot penetrate, may be more accurately described as a state of *presentative consciousness*, of which thought, or *representative consciousness*, is the reflective sequel. On the other hand, Sir W. Hamilton, by confining the term *representation* to those modes of consciousness in which there is an actual and adequate imagination of an object, has perhaps narrowed the term too much from its original meaning, and restricted it to a sense which, however convenient in the controversy concerning perception, is, out of that controversy, unnecessary and likely to mislead. The general notion of *man* is representative of many individuals in their common qualities, and of any one individual, so far as those qualities are concerned, as much as the image which the mind forms of James or John is representative of the proper characteristics of that person. The notion is generalized from the individuals, and must be ultimately verified by reference to them; and, though not resembling the individuals, and therefore incapable by itself of being depicted in the imagination, it becomes their substitute in the act of thought, just as the written word, which likewise bears no resemblance to the sound of speech, becomes the substitute and representative of the word spoken. In one respect, indeed, the thought proper may be called *representative* in a stricter sense than the imagination; for the imaginative consciousness, though representative, is presentative also, and, so far, has more affinity to sense than to thought. It is presentative of the image, which is itself an intuition, as well as representative of the object of sense. But the concept, so far as its object is concerned, is purely representative. It presents nothing on which the mind can rest as an adequate object of consciousness,—nothing which is not in its nature obviously incomplete and relative,—nothing, in short, but the fact of thinking at a particular time, and the sign in which the thought is exhibited.

Representative consciousness, like presentative, cannot be considered as forming a complete act by itself. The phenomena of intuition by themselves present nothing but a confused impression of diversity, until they are classified and distinguished from each other under separate general notions; and the notion, on the other hand, though in the ordinary exercise of thought it may be employed apart from the consciousness of the object which it represents, can only be so separated by being associated with a further representation of itself, such as is furnished by the symbols of language. Pure thought, if by that expression is meant the consciousness of general notions and of nothing else, is an operation which may perhaps be possible to higher intelligences, but which never takes place in the human mind. Our only choice lies between notions as exemplified in individual objects, and notions as represented in signs spoken or unspoken; for the sign, the clothing of our thought, accompanies our silent meditations as well as our audible utterances: εὐφήμον στόμα φροντίδος[1] is not a mere poetical metaphor, but the literal statement of a philosophical fact. Thinking, as Plato has observed,[2] is but the conversation of the soul with herself; and the instrument employed is the echo of that which forms the medium of communication with others. To this it may be added, that the notion, as represented in language, is but the substitute for the notion embodied in intuition, and derives all the conditions of its validity from the possibility of the latter; for language, though indispensable as an instrument of thought, lends itself with equal facility to every combination, and thus furnishes no criterion by which we can judge between sense and nonsense—between the conceivable and the inconceivable. *A round square*, or *a bilinear figure*, is, as a form of speech, quite as possible as *a straight line* or *an equilateral triangle*. The mere juxtaposition of the words does not indicate the possibility or impossibility of the corresponding conception, until we attempt to construct, by intuition, an individual object in accordance with it. Language, like algebra, furnishes a system of signs, which we are able to employ in various relations without at the moment being conscious of the original signification assigned to each. But what our thoughts thus gain in flexibility they lose in distinctness, and the logical and algebraical perfections are thus in an inverse ratio to each other. It therefore becomes necessary, at the end of the process, and even occasionally during the intermediate stages, to submit the result to the test to which each step has been tacitly assumed to conform; namely, the possible co-existence of the several groups of attributes in corresponding objects of intuition.[3]

From this use of language in thought arises the distinction, originally pointed out by Leibnitz, between *intuitive* and *symbolical* cognition. In the former we deal with the notions themselves, as exemplified in an individual object of intuition, real or imaginary. In the latter we deal with the same notions as represented by their symbols in language. The latter, however, is rather a substitute for consciousness than an act of consciousness itself. It implies a consciousness, indeed, of the act of thinking, but not immediately of the object about which we think.[4] Like the bank-note, it is the representative of value without having an intrinsic value of its own; and, like the bank-note, its real worth depends on the possibility of its being at any time changed for the current coin of the realm. But, as in practice the note is treated as if it were the money which it represents, so it will be convenient, in the following remarks, to treat symbolical knowledge as if it were itself the complete consciousness to which, if valid, it may be at any time reduced. We shall therefore treat both of intuitive and symbolical reflection under the general name of Representative Consciousness or Thought.

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[1] Sophocles, *Œd. Col.* 132.

[2] *Theætetus*, p. 190. "Εγωγε τὸ δοξάζειν λέγειν καλῶ· καὶ τὴν δόξαν λόγον εἰρημένον, οὐ μέντοι πρὸς ἄλλον οὐδὲ φωνῇ, ἀλλὰ σιγῇ πρὸς αὑτόν.

[3] "Plerumque, præsertim in analysi longiore, non totam simul naturam rei intuemur, sed rerum loco signis utimur, quorum explicationem in præsenti aliqua cogitatione compendii causa solemus prætermittere, scientes aut credentes nos eam habere in potestate: ita cum chiliogonum, sec polygonum mille æqualium laterum cogito, non semper naturam lateris, et æqualitatis, et millenarii (seu cubi a denario) considero, sed vocabulis istis (quorum sensus obscure saltem atque imperfecte menti obversatur) in animo utor loco idearum, quas de iis habeo, quoniam memini me significationem istorum vocabulorum habere, explicationem autem nunc judico necessariam non esse; qualem cogitationem *cœcam*, vel etiam symbolicam appellare soleo, qua et in algebra, et in arithmetica utimur, imo fere ubique." (Leibnitz, *Meditationes de Cognitione Veritate et Ideis.*)

[4] Cognitio quæ ipso idearum intuitu absolvitur, dicitur *intuitiva*, seu, rem intuitive cognoscere dicimur, quatenus ideæ ejus, quam habemus, nobis sumus conscii. E. gr. Dum arborem præsentem intueor, mihique conscius sum eorum quæ in eadem obtutu comprehendo, intuitivam arboris habeo cognitionem. Si triangulum mihi vi imaginationis tanquam in tabula delineatum, vel asserem triangularem representem, atque hujus figuræ mihi conscius sim; triangulum intuitive cognosco. Quodsi cognitio nostra terminatur actu quo verbis tantum enunciamus quæ in ideis continentur, vel aliis signis eadem repræsentamus, ideas vero ipsas verbis aut signis indigitatas non intuemur, *cognitio symbolica* est. Ita cognitionem symbolicam habeo trianguli, si cogito ipsum esse figuram tribus lineis terminatam, trianguli vero ideam nullam, multo minus linearum quibus terminatur, ac numeri ternarii earundem, ideas intueor. Similiter cognitionem chiliogoni symbolicam habeo, si verbis tacite quasi loquens mihi ipsi indigito, chiliogonum esse figuram mille lateribus terminatam, laterum vero singulorum, ac numeri millenarii, ipsiusque chiliogoni ideam nullam intueor. Quod etiam signis aliis uti possimus ad res nobis repræsentandas, præter verba, vel sola arithmetica loquitur, ubi singularibus utimur notis numericis ad numeros quoscumque repræsentandos. Habes igitur hic signa numerorum quæ sunt a verbis, quibus enunciantur, diversa. Luculentiora exempla analysis recentiorum quam algebram vulgo dicimus suppeditat, ubi formulis ex literis atque signis aliis compositis notiones rerum exhibemus." (Wolf, *Psychologia Empirica*, sect. 286, 289.

OF THE FORM AND MATTER OF THOUGHT.

The form of consciousness in general has been explained as consisting in *relation to a conscious subject*. The form of representative consciousness in particular must be ascertained by observing in what manner the subject, as a thinker, moulds into thought the raw materials furnished by intuition. The conditions under which this is done constitute the *laws of thought;* and the feature by which these laws are manifested in the product will be the *form of thought*. The former of these terms is strictly used with reference to an act of thought; the latter, with reference to its product. Conceiving, judging, and reasoning are carried on under certain *laws*. Concepts, judgments, and reasonings exhibit certain *forms*. To ascertain what these are, we must endeavour to analyse the complex act of consciousness, and to separate those elements which appear to be contributed by the reflective act of the conscious subject.

The office of thought consists in arranging the confused materials presented to it in such a manner as to constitute *an object*. This is done by *limitation* and *difference*. The object, as such, must contain a definite portion of the materials, and a portion only. Without the first of these conditions, there would be no contents out of which the object could be constructed: without the second, there would be no distinct representation of an actual object, but a confused and imperfect consciousness of the universe of all possible objects. An oak, for example, to be discerned as an oak, and as nothing else, must have certain constitutive features of its own; and these must in thought be separated from those of the surrounding objects. These two conditions of all thought, expressed in the most general terms, are the well-known logical laws of identity and contradiction, *A is A*, and *A is not not-A;* that is to say, every object, to be conceived as such, must be conceived as having a contents of its own, and as distinct from all others. But these two conditions necessarily involve a third. The object which I distinguish and that from which I distinguish it must constitute between them the universe of all that is conceivable; for the distinction is not between two definite objects of thought, but between the object of which I think and all those of which I do not think. *Not-A* implies the exclusion of A only, and of nothing else, and thus denotes the universe of all conceivable objects with that one exception. This relation, in its most general expression, constitutes a third law of thought,—that of excluded middle: *every possible object is either A or not-A*. (*Principium exclusi medii inter duo contradictoria*.) These three principles of identity, contradiction, and excluded middle, constitute the laws of *thought as thought*, and are the foundation of pure or formal logic.

Every complete act of consciousness is a compound of intuition and thought; and the portion which is due to the act of thought as such, conducted under the above laws, will be the *form of the representative consciousness*. Now, by the act of thought, the confused materials presented to the intuitive faculties are contemplated in three points of view: as a single object, as distinguished from other objects, and as forming, in conjunction with those others, a complete class or universe of all that is conceivable. We have thus the three *forms* (or, as they are called by Kant, *categories*[1]) of *unity*, *plurality*, and *totality;* conditions essential to the possibility of thought in general, and which may therefore be regarded as *à priori* elements of reflective consciousness, derived from the constitution of the understanding itself, and manifested in relation to all its products. They are thus distinguished from the *matter*, or empirical contents, by which one object of thought is distinguished from another. The matter of thought is derived from the intuitive faculties, and consists in the several *presented phenomena* which form the special characteristics of each object, as a man, a house, a tree, &c. In order to exhibit this distinction more completely, it will be necessary to notice in detail the different operations into which thought is ordinarily divided.

OF THE SEVERAL OPERATIONS OF THOUGHT.

The ordinary division of the representative faculties into conception, or simple apprehension, judgment, and reasoning, is properly a logical rather than a psychological division, and relates to the products of thought rather than to the powers or operations by which those products are generated. Viewed as products of thought, projected, as it were, out of the thinking mind, and embodied in language, the concept, the judgment, and the syllogism are expressed in different forms of speech, are susceptible of different relations one with another, and are subject to different logical rules and tests of validity. For logical purposes, therefore, they may properly be regarded as distinct objects, though susceptible of treatment upon common principles; just as the different works of the same artist, though the result of the same productive power, may be arranged in different classes and criticised from different points of view. But the logical division of products does not necessarily imply a corresponding psychological division of faculties. The same faculty, operating by the same laws, may produce different results according to the nature of the objects submitted to it; just as the same artist may produce different works out of different materials. It is necessary, therefore, before we transplant our logical divisions into the field of psychology, to inquire upon what principles the latter science is justified in distinguishing at all between various powers of the human mind.

The only natural and necessary principle of distinction between objects is the numerical diversity of individuals. All other divisions are, to a certain extent, arbitrary and artificial, and subservient to the special purposes of this or that branch of study. The naturalist may class the man and the ape together, on account of certain points of similarity in their physical structure; the moralist will place them as widely as the poles asunder, as rational and irrational, responsible and irresponsible agents. But no possible system of arrangement can make Socrates the same individual as Plato, or regard an act performed to-day as numerically one with a similar act performed three days ago. Numerically, not only intellectual operations of various kinds, but every single act of each kind, is distinct from every other. An act of reasoning which I perform today is *numerically* distinct from any similar act performed yesterday; though both may be governed by the same laws, and applied to the same objects. But in the classification of acts as *specifically* the same or different, much must depend on the purpose which we have in view, and on the utility of certain relations for certain ends. A distinction which is useful for the purposes of logic may be worthless or injurious as regards psychology.

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[1] Besides these three, which are classified as categories of quantity, Kant enumerates nine others, viz., three of quality,—reality, negation, and limitation; three of relation,—inherence and subsistence, causality and dependence, and community or reciprocal action; and three of modality,—possibility or impossibility, existence or non-existence, and necessity or contingence. But the Kantian categories are not deduced from an analysis of the act of thought, but generalized from the forms of the proposition, which latter are assumed without examination, as they are given in the ordinary logic. A psychological deduction, or a preliminary criticism of the logical forms themselves, might have considerably reduced the number. Thus the categories of quality are fundamentally identical with those of quantity,—reality, or rather affirmation and negation, being implied in identity and diversity, and limitation in their mutual exclusion. The remaining categories are, to say the least, founded on a very questionable theory in logic; and the two most important—those of substance and cause—present features which distinguish them from mere forms of thought. But these will have to be examined hereafter.

The distinction between various faculties of the internal consciousness, if made at all, must be made on a principle exactly the reverse of that by which a similar distinction is made with respect to the external senses. The bodily organs of sensation are given as locally and numerically distinct from each other, and thus furnish a pre-existing basis for the classification of their several operations. Seeing and hearing are not only distinct phenomena of consciousness, but are performed by means of distinct organs; and the faculty of seeing is at any rate so far distinct from that of hearing, that a man may be blind without being deaf, and deaf without being blind. But as regards the internal consciousness, we have no other ground for discriminating between different faculties than that which is furnished by the mental characteristics of the corresponding acts. We do not classify the acts from an acknowledged diversity of the faculties; but we attempt to classify the faculties from some admitted or supposed diversity in the acts. The acts, therefore, must, on independent grounds, be determined to be identical or distinct in species, before we can unite or separate them as related to the same or different mental powers.

The distinction between the various reflective faculties is therefore not so much to be considered with regard to its truth or falsehood as with regard to its convenience or inconvenience. The theory of distinct mental organs corresponding to distinct acts of thought is untenable on any hypothesis but that of the crudest materialism. No soberminded pyschologist ever intends to represent the mental faculties as substantially and numerically distinct portions of the mind; but, as *entia rationis*, they may furnish more or less convenient heads of classification, to connect or distinguish the similar or dissimilar mental acts or states of which we are successively conscious. In this point of view, the phenomena of conception, judgment, and reasoning, viewed merely as acts of thought, without reference to the diversity of the data from which the act commences and with which it deals, appear to furnish far more prominent features of similarity than of difference. They are effected by the same means; they are governed by the same laws; they are confined within the same limits; they admit of the same distinctions of material and formal validity. The pyschological analysis of any one may be applied, almost in the same words, to the others; and, so far as thought alone is concerned, the same mental qualities are manifested in the right performance of each. In a psychological point of view, to enumerate separate mental faculties and operations, as giving rise to the various products of thought, is, to say the least, to encumber the science with unnecessary and perplexing distinctions. It will be sufficient to refer them to the single faculty of *thought* or *reflection*, the operation of which is, in all cases, *comparison*. The unit of thought is always a judgment, based on a comparison of objects; and the several operations of thought are, in ultimate analysis, nothing more than judgments derived from different data. In order to exhibit this in special instances, it will be convenient to adopt provisionally the logical classification, and to examine the phenomena of thought under the several heads of conception, judgment, and reasoning.

OF CONCEPTION.

The ultimate object of all complete consciousness, intuitive or reflective, is, as has been already stated, an *individual;* that is to say, an object occupying a definite position in time, or space, or both. It is not, however, necessary that the individual so presented to consciousness should be discerned as such by any distinctive features. We must distinguish between an individual act of consciousness and an individual object viewed out of relation to that act. The conditions of time and space are sufficient to distinguish *the act* from every other act, and the object *at the moment of perception* from every other object; but they are not parts of *the object itself;* and they furnish no marks by which that object may be *permanently* distinguished from others. The same object may occupy different places at different times; or different objects may successively occupy the same place. Hence, in addition to these conditions, which serve only for the intuitive cognition of a single individual at a particular moment, it is necessary to select others, which may serve as marks for the reflective cognition of an individual, as such, when different objects are compared together. In any given intuition we may or may not be conscious of marks sufficient for this purpose. I may see, for example, at a distance, three men standing together. They are unquestionably three individual men, each occupying his own position in space; and this at the moment is sufficient to distinguish them from each other. But I may be unable, on account of the distance, to discern any distinctive features belonging to the objects themselves. I discern them as three men, and that is all. I cannot say whether they are fair or dark, tall or short, acquaintances or strangers. I can distinguish them by nothing but their relative positions; and these may at any moment be changed without my being able to discover it. In other words, I perceive in the individuals only such qualities as are characteristic of a class.

The above example may serve to illustrate the process of *imperfect or intuitive generalization,* which consists in directing the attention, voluntarily or involuntarily, to the common features of several objects presented to us, neglecting or not perceiving those qualities which are peculiar to each.[1] It is not a distinct cognition of the class as a class, nor of the individuals as individuals; but a confused perception of both together. To form a complete cognition of the individual, I must, by the aid of imagination, supply those distinctive features which I am unable clearly to perceive. To form a complete cognition of the class, I must separate the common attributes from their connection with a definite time and place. But how are attributes, apart from their juxtaposition in space, to be so connected together as to constitute a single object? The head and trunk and limbs of an individual man are connected together by continuity in space, and by that continuity constitute a whole of intuition, whether distinctly recognised in that relation or not. How are the attributes of mankind in general to be separated from their position in space, and yet so united together as to constitute a whole of thought? To effect this, we must call in the aid of language. The word is to thought what space is to perception. It constitutes the connecting link between various attributes,—the frame, as it were, in which they are set,—and thus furnishes the means by which the features characteristic of a class may be viewed apart from the individuals in which they are intuitively perceived, and combined into a complex notion or concept. Conception is thus, in the operations of thought, the counterpart of perception in those of sense. In the latter we are conscious of objects as extended; *i.e.*, as possessing parts related to each other by juxtaposition in space. In the former we are conscious of notions as embodied in words, and as composed of subordinate notions, which are themselves also expressed by similar symbols.

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[1] " *Si in cognitione intuitiva acquiescimus, prima intellectus operatio absolvitur, dum in ideis duorum vel plurium individuorum simul nobis occurrentibus ad ea successive attentionem dirigimus quæ in iisdem eadem sunt.* Dum enim attentionem nostram successive dirigimus ad ea quæ in ideis duorum vel plurium individuorum simul nobis occurrentibus eadem sunt; magis nobis conscii sumus quod jam in pluribus eadem percipiamus, quam quod percipiamus alia, atque adeo operatione intellectus ea a subjectis, quibus insunt, quasi separamus. Distincte igitur percipimus quæ ad genus vel speciem illarum rerum pertinent, consequenter genera et species nobis distincte repræsentamus. Quare cum generum et specierum repræsentatio sit notio, distincta autem notio intellectus operatio sit eaque prima; si in cognitione intuitiva acquiescimus, prima mentis operatio absolvitur, dum in ideis duorum vel plurium individuorum simul nobis occurentibus ad ea successive attentionem dirigimus, quæ in iisdem eadem sunt. Hoc modo patet, quomodo nobis genera et species rerum in universali repræsentare debeamus. Quod alius non detur modus in cognitione intuitiva genera et species rerum repræsentandi, ex eo intelligitur, quod universalia, seu genera et species non existant nisi in singularibus, et ad notionem entis in universali non pertineant nisi determinationes intrinsicæ pluribus singularibus seu individuis communes. Ponamus e. gr. duas arbores, cerasum atque prunum, oculis nostris una objici, ita ut utramque uno intuitu comprehendere valeamus. Quodsi jam attentionem nostram ad folia utriusque arboris simul dirigimus, nobis conscii sumus nos in utraque percipere folia, et magis quidem conscii sumus, quam quod alia vel in iisdem

Conception, apart from intuition, is only possible under the form of symbolical cognition, in which the notions are contemplated in their signs. In this form it consists in the enumeration, by means of verbal or other symbols, of the different parts constituting a given notion.[1] Conception, intuitive as well as symbolical, is thus in all cases a judgment. In intuitive conception we judge that an object now present to the mind exemplifies a given notion: we pronounce, for example, that this is a man. In symbolical conception we pronounce that the notion comprehends such and such subordinate notions as its constituent parts. But symbolical cognition supposes intuitive cognition, actual or possible, as its condition. The existence of a class is possible if the existence of individual members is possible; for the universal has no existence apart from the individual. A class really exists, if individuals exist possessing the attributes of that class: a class may imaginably exist, if we can imagine the existence of individuals possessing the corresponding attributes. But where neither perception nor imagination is possible—where the attributes are such that we cannot, either by observation or by construction, manual or mental, combine them into an individual unity of representation—the class is inconceivable, and the words by which it is represented, however separately intelligible, are, in their combination, utterly unmeaning.

Hence, as a general rule: *Conception is only possible within the limits of possible intuition*,—that is to say, those notions only are conceivable whose objects as individuals can be presented to intuition in themselves or represented in their images. It is not necessary that the intuition should in all cases actually take place; it is sufficient if, from our intuitive knowledge of the several attributes, we know that there is no incompatibility between them which renders their union in one representation impossible. I conceive a chiliogon when I define it as a regular figure of a thousand sides; but I cannot distinctly represent in the imagination a thousand sides at once; nor do I think it necessary to draw the figure in order to convince myself by actual experience of the possibility of the intuition. But I know that the property of inclosing space contains nothing incompatible with the number of a thousand sides; and that therefore the corresponding figure could be constructed, if necessary. Under this conviction, the symbolical takes the place of the intuitive cognition; and we are enabled, by the aid of language, to think of the figure in certain relations without actually constructing it.[2] In speaking of *possible intuition* as the test of conceivability, we do not mean merely the intuition of the bodily senses. Fear, or anger, or volition, or moral approbation, or any individual state of the internal consciousness, is as much an object of intuition as a sound, or a colour, or an odour; and is equally capable of being represented in an image or conceived under a general notion. Neither do we make any difference between the real and the imaginary, between the mentally and the physically possible. A centaur is as conceivable as a horse or a man, whether the actual existence of such a creature is physically possible or not. I may imagine or conceive a stone remaining suspended in air or water, or mounting upwards instead of falling downwards, though consistently with the natural law of gravitation it can do nothing but sink to the ground.

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arboribus vel extra eas una percipiamus. Quodsi jam porro attentionem nostram promovemus ad surculos in utraque arbore simul, eorundem eodem prorsus modo conscii nobis sumus. Et idem tenendum est de ramis atque truncis. Hac ratione absque omni vocabulorum vel aliorum signorum usu, ea nobis distincte repræsentamus, quæ arboribus communia sunt, atque adeo notionem hujus generis ingrediuntur, quod arboris nomine indigitamus. Atque ita simul intelligimus, quid sit mente separare ea, quæ individuis communia sunt. Neque vero utilitate sua caret nosse, quomodo in cognitione intuitiva prima intellectus operatio sese exerat, quoniam notionibus generum atque specierum claritas affunditur, si cognitio intuitiva cum symbolica conjungatur." (Wolf, *Psychologia Empirica*, sect. 326.)

[1] "*In cognitione symbolica prima mentis operatio absolvitur recensione vocabulorum, vel aliorum signorum, quibus ea indigitantur, quæ notionem rei distinctam ingrediuntur.* Etenim in cognitione symbolica tantummodo verbis enunciamus quæ in ideis continentur, vel aliis signis eadem repræsentamus, ideas vero ipsas verbis aut signis aliis indigitatas non intuemur. Quare cum in cognitione intuitiva prima mentis operatio absolvatur, si attentionem successive in idea rei ad ea dirigimus quæ notionem distinctam generis vel speciei ingrediuntur, singula autem hæc enunciabilia sint, adeoque vocabulis vel signis aliis indigitari possint; in cognitione symbolica prima mentis operatio absolvi debet recensione vocabulorum, vel repræsentatione aliorum signorum, quibus ea denotantur quæ notionem rei distinctam ingrediuntur. Ita prima mentis operatio in cognitione symbolica arboris absolvitur, si dicimus vegetabile, quod ex trunco, ramis, surculis et foliis constat: etenim sigillatim recensemus verba quibus ea indigitantur quæ in arboribus tanquam communia distinguimus, consequenter quæ notionem arboris in genere, quatenus distincta est, ingrediuntur. Non autem jam nobis quæstio est, utrum notio distincta sit completa atque determinata, atque oratione ista talis notio significetur, ut hæc definitionis loco inservire possit. Sufficit enim hic ea sigillatim enunciari quæ mente ab idea rei separantur, dum distincte nobis genus vel speciem repræsentare conamur. Pendet enim cognitio symbolica ab intuitiva, quam supponit et ad quam refertur. Quicquid igitur huic deest, idem etiam illi deesse debet." (Wolf, *Psychologia Empirica*, sect. 328.)

[2] "Quoniam vocabula sunt signa nostrarum perceptionum, vel rerum per eas repræsentatarum, dum verba recensemus quibus ea indigitantur quæ notionem rei distinctam ingrediuntur, ea singula ad perceptiones rerum in cognitione intuitiva locum habentes referre tenemur, etsi ad notionem eidem respondentem non attendamus, quod eadem ex crebro usu satis intelligere arbitremur. Quamobrem *operatio intellectus prima in cognitione symbolica præsupponit operationem ejusdem primam in intuitiva*. Hæc probe notanda sunt, ne demus sine mente sonos, nobisque persuadeamus nos notionem rei habere, dum vocabula recensere valemus, etsi *cognitionem symbolicam ad intuitivam reducere* minime valeamus: quæ reductio in eo consistit, ut ideam alicujus individui in nobis excitemus, sive sensuum, sive imaginationis ope, ac attentio nostra successive ad ea dirigatur quæ in re percepta insunt, atque deinde vocabula ad eadem referantur, prout singulis, vi significatus quem obtinent alias, subinde etiam vi etymologiæ ac compositionis, denotandis apta deprehenduntur, quatenus scilicet in etymologia vel compositione ratio denominandi latet, ad rem vocabulo denotatam manducens, nisi ipsimet vocabula ad ea significanda in cognitione intuitiva transtulerimus, atque hujus facti meminerimus." (Wolf, *Psychologia Empirica*, sect. 329.)

Conception without an accompanying intuition is only possible, as we have already observed, by means of symbols; but the thought which accompanies every complete intuition, and by which various presented attributes are regarded as constituting a whole, is an act of precisely the same kind, and may therefore properly be called by the same name. Conception may thus be distinguished as of two kinds:—*Symbolical Conception,* in which a general notion, represented in language, is regarded as composed of other subordinate notions similarly represented; and *Intuitive Conception,* in which an individual object, present to sense or imagination, is regarded as a whole composed of certain presented parts. By this the object is *thought under a concept;* being thereby separated from the surrounding objects of intuition, and regarded as a whole by itself.[1] The former kind of conception is based on the latter, and derives its validity from it. It is in the latter, therefore, that the form and laws of conception will be most clearly exhibited. We must therefore analyse the complex act of intuitive conception, in order to detect, in the whole so conceived, the part contributed by the reflective faculty, and the laws under which it operates.

It has been already observed that intuition and thought, the presentative and the representative consciousness, can be distinguished from each other, as actual states of mind, only logically, not really. To the recognition of either, as a fact of consciousness, the presence of both is indispensable. To discern the element contributed by conception to the cognition of an object of consciousness as such, we may revert, for the moment, to the supposition of a being susceptible of a diversity of intuitions, but with no power of discerning wherein that diversity consists. In other words, we must suppose him divested of the faculty of *comparison.* In the exercise of sight, for example, he might at any moment be dimly conscious that he saw something; he might also be dimly conscious that he had seen something before; but he would not be conscious whether the two objects were the same or different in species; for this implies a reflective cognition of each under a separate notion. By the act of conception I discern a particular object as such; and this implies at the same time a consciousness of its difference from something else. The act of reflection has thus added a new element to the phenomena of intuition, namely, a consciousness of their relation to each other. The mere presence of an object affecting the organ of sight does not in itself imply that any other object accompanies or has preceded it; but the recognition of it as this object rather than that, does so. Conception, whether intuitive or symbolical (for the latter is but the substitute for the former), thus implies the cognition of objects under separate notions, and this cognition constitutes the common or formal feature of the act of conceiving, being unaffected by any diversity in the nature of the objects conceived. To ascertain the laws of conception, we must therefore ask what this cognition of objects in all cases supposes: in other words, what are the relations implied in the knowledge of an object as such. In the first place, the object is *discerned,* or separated from all others; and this separation implies two relations,—*identity* and *diversity.* The consciousness of identity is at the same time the consciousness of difference; I discern a thing by knowing it as what it is, and by distinguishing it from what it is not. In the second place, the cognisance of this relation between objects implies also their *mutual relation to a common consciousness.* I am conscious of the distinction of one thing from another, by including both as modes of one continuous conscious existence. Without this, memory would be impossible, and without memory there could be no comparison. We have thus the three forms of unity, plurality, and totality, manifested as the necessary relations with which the mind, in the act of conception, invests the materials furnished by intuition. To conceive any object A as such, I must distinguish it from all that is not A, and I must regard A and *not*-A as constituting between them the universe of my consciousness. These requirements are expressed by the three laws of identity, contradiction, and excluded middle, which may thus be regarded as the universal or formal conditions of every act of conception as such, in contradistinction from the special or material conditions which are necessary to the conception of this or that particular class of objects only.

From the above exhibition of the laws and forms of thought in general, as manifested in the act of conception, it will be easy to deduce, in a somewhat amended enumeration, those special forms which have been treated by logical writers as distinctive of the concept proper.[2] The concept is necessarily conceived as *one,* as *one of many,* and as *constituting with the many an universe of the conceivable.* From the last of these three conditions it follows, that the concept must possess a generic or universal feature, by which it is characterized as a concept in general, or a member of the conceivable universe. From the second it follows, that it must also possess a differential or peculiar feature, by which it is distinguished from all others. And from the first it follows, that these two features must be united into a single whole. Hence every concept, as such, must possess in some degree the attributes of *distinctness,* as having complex contents, capable of analysis into genus and difference: of *clearness,* as being by one portion of its contents distinguishable from other notions; and of *relation to a possible object of intuition,* inasmuch as the unity of a complex notion depends, not on a mere juxtaposition of terms, but upon its being the representative of one object.[3] These three forms may be otherwise denominated (for the difference is merely verbal) *comprehension, limitation,* and *extension.* As having complex contents, every concept *comprehends* certain attributes; as distinguishable from others, it is *limited* by its specific difference; and, as representative of a class of possible objects, it has a certain field over which it is *extended.* The forms of the concept proper may thus be indifferently enumerated, as distinctness, clearness, and relation to an object; or as comprehension, limitation, and extension.

We have thus exhibited the general laws of thought in their relation to those objects with reference to which the thinking act is usually distinguished as conception. But though no conception is possible, except in conformity with these laws, it must not, therefore, be concluded that conception is possible in all cases in which they are not transgressed. An object may be inconceivable in two ways,—*essentially* or *formally*, because the attempt to conceive it involves a violation of the laws of thought; and *accidentally* or *materially*, because of the absence of certain preliminary conditions, whose existence must be presupposed before thought comes into operation. By the laws of thought, a concept must have distinctive contents; it must not comprehend two contradictory elements; and it must be contained under one or the other of the contradictory notions which constitute the universe of thought. Where these conditions are not observed, the object is formally or essentially inconceivable. Thus pure Nothing which has no contents, and also the indefinite notions indicated by the terms Being, Thing, Existence in general, which have no definite contents, are formally inconceivable, as violating the law of identity: they are not an A as distinguished from a *not*-A. So, again, we are formally unable to conceive the same surface as both black and *not*-black, which involves a violation of the law of contradiction; nor yet can we conceive it as neither one nor the other; for this is prohibited by the law of excluded middle. But the accidental or material inconceivability of objects depends on other conditions. The materials of thought are furnished by the phenomena of the senses or of some other intuitive faculty; and hence, when the intuition is wanting, conception is impossible, as having no data upon which to operate. Thus, a blind man can form no conception of colours, and a deaf man can form no conception of sounds,—not because sounds and colours are in themselves inconceivable, but because the preliminary intuition, which should furnish the materials of the conception, is deficient. And so likewise any man, though in the full possession of his senses, is unable to form a conception of a colour which he has never seen, or of a sound which he has never heard, or of a savour which he has never tasted; or, at least, he can form only such an imperfect conception as may be furnished by its supposed likeness to some object of his actual experience,—a conception necessarily defective, as not containing the specific difference which characterizes the object as such, and which actual experience alone can furnish. Objects accidentally inconceivable may be divided into two classes:—those which are deficient in the *matter* of the intuition, and those which are deficient in the *form;* for it must be remembered that the form of intuition becomes part of the matter of thought; and that both these classes are therefore, so far as conception is concerned, inconceivable *materially* or *accidentally*. The form of intuition is to be found in the general conditions of space and time, which are common to all external or internal intuitions respectively, as such: the matter is to be found in the special affections of this or that mode of external or internal sense, by which one object is distinguished from another. Upon the necessary relations of space and time are founded the two sciences of geometry and arithmetic; and a notion which violates the principles of either of these may be classified as inconceivable from a defect in the form of intuition. Thus it is impossible to conceive a figure bounded by two straight lines, or an odd number which is the sum of two even ones; because the two straight lines cannot be perceived or imagined as occupying such a position in space as is necessary before we can include them under the general concept of a figure; and the two even numbers cannot occupy such a succession in time as is necessary to the formation of the concept of an odd number. These notions are not, as some writers have supposed,[1] logically self-contradictory, and therefore formally inconceivable; they are not inadmissible in their general character as thoughts, but in their special character as thoughts about figures or numbers. In one respect they differ considerably from the other class of materially inconceivable objects, in which the impossibility arises only from a deficiency in actual experience of the matter of intuition, such as has been supposed in the case of an unknown colour or sound. The latter may become conceivable by a mere extension of experience, without any change in our bodily or mental constitution. The former, being dependent on the subjective conditions of intuition, could not become conceivable without a change in the constitution of our intuitive faculties. This difference will be more fully examined when we come to treat of the distinction between necessary and contingent truths.

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[1] "The understanding, thought proper, notion, concept, &c., may coincide or not with imagination, representation proper, image, &c. The two faculties do not coincide in a general notion; for we cannot represent man or horse in an actual image without individualizing the universal; and thus contradiction emerges. But in the individual, say Socrates or Bucephalus, they do coincide; for I see no valid ground why we should not *think,* in the strict sense of the word, or *conceive* the individuals which we *represent.*" (Sir W. Hamilton, *Discussions,* p. 13.) We may go even beyond this, and regard conception as coinciding, not merely with the *imagination,* but with one element of the *perception* of an individual object. For the combination of individual parts into a whole is a cognition of *relations,* and, as such, is properly an act of the understanding, operating by means of concepts.

[2] See Kant, *Logik,* sect 2. Fries, *System der Logik,* sect. 20. The former places the form of a concept in its universality; the latter adopts the same view, subdividing universality into extension and comprehension.

[3] Arist. *Metaph.* vi. 12. Ἐπὶ μὲν γὰρ τοῦ ἄνθρωπος καὶ λευκὸν πολλὰ μέν ἐστιν, ὅταν μὴ ὑπάρχῃ θατέρῳ θάτερον, ἓν δέ, ὅταν ὑπάρχῃ καὶ πάθῃ τι τὸ ὑποκείμενον ὁ ἄνθρωπος· τότε γὰρ ἓν γίγνεται καὶ ἔστιν ὁ λευκὸς ἄνθρωπος. *Ibid.* vii. 6. Ὁ δ᾽ ὁρισμὸς λόγος ἐστὶν εἷς οὐ συνδέσμῳ καθάπερ ἡ Ἰλιάς, ἀλλὰ τῷ ἑνὸς εἶναι.

Before concluding this part of our subject, it will be necessary to say a few words on the controverted question of the processes usually regarded as subsidiary to conception, namely, abstraction and generalization. The account usually given of these processes by writers on logic cannot be regarded as accurately exhibiting the psychological phenomena connected with the passage from intuition to thought; and the question derives additional interest from the controversy which has been raised by philosophers of eminence concerning the reality of the processes themselves.

The ordinary logical account is to the following effect:—We examine, it is said, a number of individual objects, agreeing in some features and differing in others: we *abstract* or separate the points in which they agree from those in which they differ; and we *generalize*, or construct a common notion, represented by a common name, out of the features of similarity so separated from the rest; which common notion becomes thus indifferently applicable to all the individuals from which it was derived. The process, as thus described, appears to presuppose the very act of conception to which it is represented as giving rise. If, for example, I am to form a general notion of *man* by examining the individuals Peter, James, and John, and by separating the accidents of complexion, stature, expression of countenance, &c., from the human form which is common to all, it is obvious that I must previously have formed general notions of the parts so separated from each other. Before I can say, this man has blue eyes and that man has black; and the colour of the eyes may therefore be set aside as accidental; I must have discerned, by means of concepts, the eyes as such from other features, and the colours blue and black from other visible qualities. If these concepts, according to the above theory, are formed by means of a previous abstraction, the same difficulty is repeated. Conception supposes abstraction, and abstraction again supposes conception, and the explanation thus runs in a constantly recurring circle.

The error of the theory consists in supposing that the individual is discerned *as such* before the universal. In the confused consciousness, if it can be called consciousness at all, which alone would be possible in an act of sensation unaccompanied by thought, we could not be said to discern either likenesses or differences. We should not be able to distinguish one individual from another, or to compare them together as like or unlike. As soon as thought is awakened, the general notion is perceived in and along with the individual which is discerned under it; and it is impossible to distinguish an individual as such from others, without at the same time being conscious of the notion which that individual exemplifies. Indeed, properly speaking, every collection of individual attributes is potentially the representative of a class; for there is nothing in the attributes themselves to prevent their being exhibited by more than one object. In one sense, indeed, it might be said that our cognition of the class is prior to that of the individual. For, in the development of consciousness by the aid of language, resemblances are noticed earlier than differences; and even the names distinctive of individuals are at first associated only with their generic features. Children, says Aristotle, at first call all men *father*, and all women *mother*, but afterwards they distinguish one person from another.[1] By the aid of language, our first abstractions are in fact given to us already made, as we learn to give the same name to various individuals presented to us under slight and at first unnoticed circumstances of distinction. The name is thus applied to different objects long before we learn to analyse the growing powers of speech and thought, to ask what we mean by each several instance of its application, and to correct and fix the signification of words at first used vaguely and obscurely.

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[1] Among others may be mentioned Leibnitz, *Théodicée*, sect. ii., p. 480, ed. Erdmann; Stewart, *Elements*, part ii., ch. i.; and Whately, *Logic*, appendix on Ambiguous Terms, *v. Impossibility*.

The nature of the general notion or concept itself has been no less a point of controversy among philosophers than the process by which it is formed. According to Locke,[2] the general idea of a triangle is an imperfect idea, "wherein some parts of several different and inconsistent ideas are put together." As limited to no particular kind of triangle, but including all, it must be "neither oblique nor rectangular, neither equilateral, equicrural, nor scalenon; but all and none of these at once." The general idea, as thus described, Berkeley easily perceived to be self-contradictory, and the doctrine suicidal. "I have a faculty," he says, "of imagining or representing to myself the ideas of those particular things I have perceived, and of variously compounding and dividing them. I can imagine a man with two heads, or the upper parts of a man joined to the body of a horse. I can consider the hand, the eye, the nose, each by itself, abstracted or separated from the rest of the body. But then, whatever hand or eye I imagine, it must have some particular shape and colour. Likewise, the idea of man that I frame to myself must be either of a white, or a black, or a tawny, a straight, or a crooked, a tall, or a low, or a middle-sized man. To be plain, I own myself able to abstract *in one sense*, as when I consider some particular parts or qualities separated from others, with which, though they are united in some object, yet it is possible they may really exist without them. But I deny that I can abstract one from another, or conceive separately, those qualities which it is impossible should exist so separated; or that I can frame a general notion by abstracting from particulars in the manner aforesaid."[3] On these grounds, the bishop maintains that things, names, and notions, are in their own nature particular, and are only rendered universal by the relation which they bear to the particulars represented by them.

The remarks which have been made above, on the distinction between intuitive and symbolical knowledge, and on the office of language in promoting distinctness of intuition as well as of conception, may assist in placing this controversy on a more satisfactory footing. The error of Locke, as Berkeley clearly perceived, consisted in regarding abstraction as a positive act of thought, instead of the mere negation of thought. Abstraction is nothing more than non-attention to certain parts of an object: we do not positively think of the triangle as neither equilateral, nor isosceles, nor scalene; but we think of the figure as composed of three sides, without asking the question whether those sides are equal or unequal. On the other hand, Berkeley, in maintaining that all notions are in their own nature particular, has overlooked the fact, that thought, and, through thought, language, is necessary to distinguish the particular as particular, no less than the universal as universal; and that we are thus enabled, both in intuitive and in symbolical cognition, to discern generic attributes, and to constitute them an object of conception, without being conscious of the particulars by which they are accompanied. I see a man at a distance, and I know him to be a man; here is intuition and conception combined. But I am not near enough to discern either his stature or his complexion; and though, if my attention is called to the point, I cannot help admitting that he must be of a certain size and a certain colour; yet the visible object presents neither the one nor the other; and it is not necessary that my attention should be called to them at all. It is true that the visible object, as a surface, is coloured; but this colour does not enter into my notion of the thing represented. The faint blue tint that marks a distant object is not included in my conception of the object as a man, and my sight is too feeble to enable me to supply any other. Here, then, is a distinct cognition of generic attributes as such,—attributes which are indeed perceived as existing in an individual, but which contain no distinctive feature by which the individual can be recognised as such. The abstraction becomes still greater when the conception is purely symbolical; as we are thus enabled to think of the attributes without being at the moment conscious of their coexistence in any individual whatever. Berkeley mistakes the test of conception for the act of conception itself. Conception is not identical with imagination; though the latter process is so far the test of the former, that nothing can be conceived as constituting a class, which is absolutely and in its own nature incapable of being imagined as existing in an individual.

The length to which our remarks have run on the subject of conception will enable us to be more brief in our treatment of the remaining operations of thought, which are nothing more than the same faculty of comparison applied to different objects.

OF JUDGMENT.

Judgment, in the limited sense in which it is distinguishable from consciousness in general, is an act of comparison between two given concepts, as regards their relation to a common object. Omitting those judgments which involve merely the enumeration of the attributes comprehended in a concept (the *analytical* or *explicative judgments* of Kant), which may be more properly classified as acts of conception; and confining ourselves to those in which the contents of the given concepts are distinct from each other (the *synthetical* or *ampliative judgments* of Kant), we may distinguish the form from the matter of judgments,—the part contributed by the act of judging itself, from the preexisting materials on which it operates,—as follows. The concepts being distinct from each other in contents, their relation to a common object cannot be ascertained by any mere examination of those contents: this relation, therefore, as well as the concepts themselves, must be given prior to and out of the act of comparison. In other words, the relation between the two concepts must be given in an act of intuition, pure or empirical, imaginary or real, before we can decide by an act of judgment that such a relation does or does not exist. For example: in order to form the judgment "two straight lines cannot inclose a space," I must not only know the meaning of the terms employed, but I must also, by the aid of imagination, construct a representation in my mind of two actual straight lines and their actual positions in space. I must perceive that these two straight lines are incapable of inclosing a space, before I pronounce the universal judgment concerning straight lines in general. Here the relation between the two

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[1] *Phys. Ausc.* i. 1.

[2] *Essay*, b. iv., chap. vii., sect. 9.

[3] *Principles of Human Knowledge*, Introduction, sect. 10.

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concepts is presented in a *pure* or *à priori intuition*,—*i.e.*, in an intuition containing no adventitious element external to the mind itself. Again, in order to form the judgment "gold is heavy," supposing that my conception of gold does not in itself include the attribute of weight, I cannot, by merely thinking of gold as a hard, yellow, shining body, determine what effect it will produce when laid upon the hand. I must actually place an individual piece of gold upon my hand, and ascertain by experience the fact of its pressure. Here the relation between the two concepts is presented in a *mixed* or *empirical intuition ; i.e.*, in an intuition caused by the presence of a body external to the mind itself. The examination of these constituent elements will enable us to distinguish between the matter and the form of thought as exhibited in the act of judgment.

If I poise a piece of gold in my hand, in order to ascertain whether it is heavy, the presented phenomena belong to distinct acts of sensation. The evidence of sight attests the presence of a round, yellow, shining body; the evidence of touch, or rather of muscular pressure, attests its weight. To unite these attributes, as belonging to one and the same thing, is an act, not of sensation, but of thought. The mere sensation, aided by the concepts, presents us with three things—the body which is seen, the pressure which is felt, and a certain temporal and local juxtaposition of the two. To combine the presented attributes as belonging to one thing; to pronounce that it is *the gold* which is heavy, is an act of thought, constituting a judgment. Here, then, we have one form of judgment, expressed in the copula "gold *is* heavy:" this indicates the identification of two concepts as related to a common object; an identification usually known as the *quality* of the judgment.

The same is the case with the *quantity* of judgments. I see a number of balls lying on a table, and pronounce at once that they are all white; I see another collection, and assert in like manner that some are white and some black. Here the senses, even when aided by the concepts in distinguishing the balls as such, yet present to us only individual objects. *This*, *this*, and *this* are within their province; but they know nothing of *all* or *some*. It is by an act of thought that the several individuals are regarded as constituting a whole, and a judgment pronounced concerning that whole or a portion of it.

A third form of the judgment, as indeed of all thinking, is *limitation*. In predicating one notion of another, I at the same time necessarily exclude everything to which that predicate is opposed, and thereby limit the subject to one alone of those contradictory determinations which make up the universe of thought. In asserting, for example, that gold is heavy, I as much exclude it from the class of imponderables as I include it within that of bodies possessing weight. The canon that *predication is limitation* is now, indeed, universally admitted as an axiom in philosophy;[1] and the various metaphysical systems of modern Germany, since the days of Kant, may be briefly described as so many attempts to evade the consequences of this principle by constructing a philosophy of the unlimited on a basis independent of logical predication.

Psychology.

These three forms of the judgment,[2] like those of the concept, may be regarded as special manifestations of the three conditions of thought in general—unity, plurality, and totality. As *one*, the judgment possesses *quality*, exhibited in its copula, by which, as a connecting link, it is constituted a single act of thought. As *one out of many possible judgments*, it is *limited* by its predicate; and as *a whole composed of parts*, it represents an object of thought, which, whether it be one individual or many, contains in itself the several attributes indicated by the terms. This relation to an object is expressed by the *quantity* of the judgment, whereby one, some, or all of the members of a class are pointed out as an object possessing various attributes and combining them into a whole.

The three highest laws of thought are likewise operative in the act of judging, as in that of conceiving. This may be shown by ascertaining what are the universal conditions under which the judgment, *as a thought*, is possible. Of course we have nothing to do with the material conditions under which this or that judgment is possible *as a fact*. The latter conditions are special, not general, and apply to this or that particular judgment in its relation to its objects; not to all possible judgments in their relation to the thinking subject. As far as the laws of thought are concerned, it is indifferent whether we assert that the earth goes round the sun, or the sun round the earth; the latter proposition being logically as valid as the former, however incompatible with the facts of astronomy. The universal conditions of the possibility of any judgment as a thought may be ascertained by the following question:—Given any concept A, under what conditions may another concept B be predicable of it? The particular objects signified by A and B are supposed to be unknown; the question of the logical validity of the thought being thus kept free from all admixture of material elements. In the first place, the concept B must have definite contents: it is to be a predicate limiting A. It is therefore a portion, and a portion only, of the universe of possible concepts distinct from A. This is expressed by the law of excluded middle. Every concept distinct from A is either B or *not*-B. In the second place, the concept B must contain no attribute logically incompatible with A. This is expressed by the law of contradiction. In the third place, the concepts A and B, when united in a judgment, must be regarded as representing one and the same object; that which is A is also B. This is expressed by the law of identity. A in becoming B remains identical with itself. This apparent paradox of identity in diversity constituted one of the earliest puzzles in metaphysics, and gave rise to a scepticism which, refusing to admit without explanation the laws of thought themselves, consistently denied the possibility of uniting two notions in a judgment.[3] Whether the doubt thus suggested can be satisfied by ontology, is a question which cannot be considered at present. In a psychological point of view, it is sufficient to say that such is the form which thought necessarily assumes. The office of psychology is to exhibit the laws of thought as they actually exist; it cannot undertake to vindicate them, or to explain why the human mind is constituted as it is.

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[1] See, for example, among others, Fichte, *Ueber den Grund unseres Glaubens an eine göttliche Weltregierung*, p. 16 (*Werke*, v., p. 187): *Gerichtliche Verantwortung*, p. 47 (*Werke*, v., p. 265); *Bestimmung des Menschen* (*Werke*, ii., p. 304). Hegel, *Logik*, p. i., b. ii., chap. 2.; p. ii. chap. 2 (*Werke*, iv., p. 26; v., p. 70).

[2] Kant (*Kritik der r. V. Transc. Anal.*, B. i., Abschn. 2; *Logik*, sect. 20) admits four forms of the judgment,—quantity, quality, relation, and modality. The two first have been admitted above. That of relation, under which head Kant classes the division of judgments into categorical, hypothetical, and disjunctive, is based on a very questionable position of the ordinary logic. If, as appears to be the case, hypothetical and disjunctive judgments, so far as they are judgments at all, are reducible to categoricals, relation, instead of being a special form of judgment, becomes a term equivalent to judgment in general. As regards modality, it may perhaps be more accurately referred to the matter than to the form of the judgment. The only judgments necessary *as thoughts* are those in which the subject logically contains the predicate: the only judgments impossible *as thoughts* are those in which the one term contradicts the other. These, as analytical judgments, have been above classed under the head of conception. All other judgments, *as thoughts*, are contingent, and become necessary or impossible only as thoughts about this or that particular object. It is not logic nor metaphysics, but geometry, which tells us that the angles of a triangle *must be* equal to two right angles.

[3] Plato, *Theæt.*, p. 201. Ἐγὼ γὰρ αὖ ἐδόκουν ἀκούειν τινῶν ὅτι τὰ μὲν πρῶτα οἱονπερεὶ στοιχεῖα, ἐξ ὧν ἡμεῖς τε συγκείμεθα καὶ τἄλλα, λόγον οὐκ ἔχοι· αὐτὸ γὰρ καθ᾽ αὑτὸ ἕκαστον ὀνομάσαι μόνον εἴη, προσειπεῖν δὲ οὐδὲν ἄλλο δυνατόν, οὔθ᾽ ὡς ἔστιν οὔθ ὡς οὐκ ἔστιν. *Sophist.* p. 251. Εὐθὺς γὰρ ἀντιλαβέσθαι παντὶ πρόχειρον ὡς ἀδύνατον τά τε πολλὰ ἓν καὶ τὸ ἓν πολλὰ εἶναι, καὶ δή που χαίρουσιν οὐκ ἐῶντες

OF REASONING.

The third operation of thought, reasoning, is likewise an act of comparison between two concepts; and only differs from judgment in that the two concepts are not compared together directly in themselves, but indirectly by means of their mutual relation to a third. As the concept furnishes the materials for the act of judging, so the judgment furnishes the materials for the act of reasoning. The matter of the syllogism thus appears in the several propositions of which it is composed, and which vary in every different instance; its form appears in the manner in which those propositions are, in the act of reasoning, connected together as premises and conclusion. This connection consists in the recognition of a relation of identity or contradiction between the terms given in the antecedent and those connected by the reasoning act itself in the consequent. The forms and laws of reasoning may thus be ascertained by the following question:—"Given two judgments (no matter what may be their material signification), what relations must exist between them, to warrant us in inferring a third judgment as their consequent?"

In the first place, the premises and the conclusion must stand to each other in the relation of condition and conditioned. As the predicate of a judgment limits and determines the subject, so the premises of a syllogism must limit and determine the conclusion. *Limitation* is thus a form of reasoning, as of all thinking, and exhibits, as has been shown in the case of judgment, the operation of the law of excluded middle. The conclusion, to be determined, must be one of two contradictory possibilities. In other words, the premises must be so related to each other as to necessitate *some conclusion.* If the connection between A and B, as exhibited in the premises, be such that, *as far as those premises are concerned*, we are not necessitated to infer that A is either B or *not*-B, there is no determination of a conclusion, and consequently no reasoning.

In the second place, since the concepts A and B are not compared together directly, but through the medium of a third, it is necessary that this third concept should be successively compared with each of the others. This comparison results in a relation either of identity or contradiction; the subjects of the two concepts being pronounced identical whenever the premise is affirmative, and contradictory whenever it is negative; and a similar relation being consequently inferred to exist between the concepts compared together in the conclusion. Hence the reasoning in all affirmative syllogisms is governed by the law of identity, and in all negative syllogisms by that of contradiction. Thus, when we reason "All C is (some) B; all A is (some) C: therefore all A is (some) B; the law which determines the conclusion is, that whatever is identical with a portion of C is identical with a portion of that which is identical with all C. Here is the principle of identity: "Every portion of a concept is identical with itself." Again, when we reason "No C is (any) B; all A is (some) C: therefore no A is (any) B,"[1] the law which determines the conclusion is, that whatever is identical with a portion of C cannot be identical with that which is contradictory to all C. Here is the principle of contradiction: "No portion of a concept can contradict itself." The forms which the syllogism exhibits, as exemplifying the above laws, are those of *mood* and *figure*, affirmative or negative, which determine what relations of identity or contradiction in the premises of a syllogism may legitimately determine a similar relation in the conclusion. Here, again, we see a special exemplification of the three general forms of unity, plurality, and totality; the middle term, in its twofold capacity of self-identity and double comparison, constituting the syllogism both a single thought and a whole composed of parts; while the determination of a definite conclusion and the exclusion of others indicates its limited character as one thought out of many.[2]

The further examination of the syllogistic forms belongs to the province of logic. Before dismissing this portion of our subject, however, it may be necessary to say a few words in defence of the character which throughout the preceding pages has been assigned to the general laws of thought;—that of identical judgments, in which the predicate expresses the same notion that is already given in the subject. The reader who remembers the contemptuous chapter of Locke on Trifling Propositions,[3] or the equally contemptuous observations of Stewart on the Aristotelian Logic,[4] may be astonished to find these despised propositions elevated to the character of laws of mind, and placed at the head of all thought. In truth, however, the position thus assigned to them is not only justified by the analysis of the act of thought, but is a necessary consequence even of the doctrines of Locke himself. Supposing that the act of thinking is governed by general laws at all (and that it is so, is manifest from the inability to conceive absurdities), such laws can clearly impart nothing in the way of instruction or the discovery of new truths. A new truth is in its very nature partial: it is new only because it is partial, because it is the discovery of the particular attributes of some particular thing or class of things. In a psychological point of view, the determination of the laws of thought (be their character as judgments what it may) is as much a new truth as any other, being the discovery of a particular fact in the constitution of the human mind. But when we consider the same laws logically, in their application to the products of thought, how is it possible for any new truth to be determined by them? As general laws, they have no special relation to this object of thought rather than that; and it is upon such special relations that the

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ἀγαθὸν λέγειν ἄνθρωπον, ἀλλὰ τὸ μὲν ἀγαθὸν ἀγαθόν, τὸν δὲ ἄνθρωπον ἄνθρωπον. Arist. *Metaph.* iv. 29. Διὸ Ἀντισθένης ᾤετο εὐήθως μηθὲν ἀξιῶν λέγεσθαι πλὴν τῷ οἰκείω λόγῳ ἓν ἐφ' ἑνός, Simplicius *in Arist. Phys.* f. 20. (Scholia ed. Brandis, p. 330.) Οἱ δὲ ἐκ τῆς Ἐρετρίας οὕτω τὴν ἀπορίαν ἐφοβήθησαν ὡς λέγειν μηδὲν κατὰ μηδενὸς κατηγορεῖσθαι, ἀλλ αὐτὸ καθ' αὐτὸ ἕκαστον λέγεσθαι, οἷον ὁ ἄνθρωπος ἄνθρωπος καὶ τὸ λευκὸν λευκόν. (Cf. Zeller, *Philosophie der Griechen*, ii., p. 115.)

[1] In expressing the quantity of the predicate in our propositions, we have adopted the rule laid down by Sir W. Hamilton as the basis of a new analytic of logical forms, viz., *to state explicitly what is thought implicitly.* The particular instances selected, however, only express the rules of the ordinary logic, which tell us that the predicate is distributed always in negative propositions, and never in affirmative; *i.e.*, that it is actually thought as universal in the one case and particular in the other.

[2] In the Kantian logic, which adopts the ordinary classification of syllogisms, the categorical syllogisms are referred to a modified form of the laws of identity and contradiction, which Kant treats as one law; while hypothetical syllogisms are regarded as dependent on the principle of sufficient reason, and disjunctives on that of excluded middle. But Kant too hastily accepted the ordinary logical classification. If, as I believe to be the case, all hypothetical and disjunctive reasonings, so far as they are reasonings at all, may be reduced to the categorical form, it follows that all syllogisms will depend on the laws of identity and contradiction, and, in a subordinate manner, on that of excluded middle. The principle of sufficient reason, in its logical form, is, properly speaking, not a law of thought, but only a statement that all thought must be governed by some law or other.

[3] *Essay*, b. iv., chap. viii.

[4] *Elements*, part ii., chap. iii.

discovery of every new truth must depend. Material knowledge arises from the observation of differences; the essential feature of laws of thought must be abstraction from all differences.[1] A necessary law of all thinking, which shall at the same time ascertain the definite properties of a definite class of things, is a contradiction in terms; for it is optional, and therefore contingent, whether we shall apply our thoughts to that particular class of things or not. But if all men have been thinking, some on this thing, some on that, but all under one code of laws, what marvel if, when their attention is called to those laws, they should recognise them as what they have all along virtually acknowledged. Herein lies at once the explanation and the justification of the so-called frivolity of principles of this kind. They can determine only the general attributes common to all objects of thought as such; and, as every object of thought is such from the moment we are able to think of it at all, these attributes must constitute the very identical judgments which logic has been so much decried for offering. To this it may be added, that Locke, who denies the existence of innate ideas, and maintains that man cannot by any power of thought invent or frame a new simple idea,[2] is the very last philosopher who should have condemned the laws of thought as conveying no instruction. For if the principles of pure thought are competent to add anything to the matter already given, the act of thought can in so far invent or frame a new idea; and this brings us back of necessity to the theory of innate ideas. If, on the other hand, the reflective faculty can only modify the materials already given to it, it follows that identical judgments are not mere verbal frivolities, but fundamental laws of the human mind.

OF THE ASSOCIATION OF IDEAS.[3]

The laws of thought, properly so called, indicate the necessary conditions under which one thought suggests another, as involved in it *à priori*, and in its own nature, irrespectively of the particular experience of individual thinkers. These conditions may be reduced to the two relations of identity and contradiction; and the principles in which these relations are expressed may be called necessary or *à priori* laws of thought as thought. We have now to consider another connection, by virtue of which one thought accidentally suggests another, as associated with it in the past experience of this or that individual thinker. The conditions under which this suggestion most frequently takes place may be exhibited as the general conditions of the phenomenon usually known as the association of ideas; and the laws in which these conditions are expressed may be called contingent or empirical laws of thought in its accidental relations. The phrase *association of ideas* seems to be now so completely established in philosophical language, that it is hardly possible to put it aside in favour of a more accurate expression; but in retaining it, we must, to avoid misapprehension, point out that it is in many respects defective. In the first place, the term *association* expresses only a very limited portion of the phenomena,—those, namely, in which the elements associated together are consciously distinguished from each other, and equally correlative; whereas in many of the most important phenomena of this class the combined elements are so completely fused together that the constituent ingredients can with difficulty, if at all, be detected in the compound; and in others the relation is almost entirely on one side,—the first element suggesting the second far more strongly than the second suggests the first. In the second place, to speak of the associated objects as *ideas* naturally tends to limit the relation to modes of cognition, to the exclusion of desires and feelings.[4] On this account it would be better to describe the phenomena in question, in more general language, as those of *related modes of consciousness*,—a phrase which is indifferently applicable to equal and unequal correlatives, and to all the states of mind which are capable of connection among themselves and with each other.

In one sense, indeed, our whole consciousness may be said to be dependent, not indeed on the *association*, which term implies a previous separate existence of the objects associated, but on the *coexistence* or *relation* of ideas or modes of consciousness to each other. For consciousness is only possible as an apprehension of differences; and this apprehension is only possible by the simultaneous cognition of the objects distinguished from each other. I can perceive, for example, a particular colour only by its contrast to some other colour or to a surrounding darkness. I can be conscious of a state of pleasure or pain only by its contrast to some other mental state preceding it; and this contrast implies a juxtaposition of the two states at the moment of the transition from one to the other. Consciousness is only realized under the condition of space or time; and space and time can only be discerned by means of the relation between objects contiguous in the one or successive in the other. These general relations, as the conditions of all consciousness, have been already noticed in the preceding pages, and need not be again examined here.

Nor yet is it necessary to dwell on those special relations which are necessary to the existence of any particular mode of consciousness as such, and do not merely regulate its subsequent reproduction. Our *complex ideas*, as they are called (and all ideas are in some degree complex), are instances of this class of relations. My perception of a horse, for example, is compounded of a certain colour, shape, and arrangement of parts,—all which are simultaneously presented to the eye, and form the conditions of my cognition of the horse as such. This, again, is not a case of suggestion or association, since none of the ideas thus given in combination can be regarded as the cause or antecedent condition of the rest.

Nor, again, should we include under the head of association the logical consequence of one notion from another,—a consequence intrinsic and essential to the thoughts themselves, and not dependent on the experience of a particular thinker. These consequences are all reducible to the relations of identity and contradiction, and imply, not the suggestion of one notion by another, but the analysis of a notion already given into the parts which it implicitly contains, and which are virtually given along with it. Under this class will come those relations which Sir William Hamilton has specified as *logical* or *objective* trains of thought,—in which "thoughts, though denoted by a single and separate expression, implicitly contain a second; which second the process of thinking explicates, but does not determine to succeed."[5] Such is the case with all terms which in their signification are essentially relative to each other. The thought of a parent is relative to that of a child; that of a greater to a less; that of a cause to an effect. But then the term *parent*, in itself, means parent of a child; the term *greater* means greater than a less; the term *cause* means cause of an effect. Hence, as Sir W.

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[1] See Kant, *Logik*, Einleitung, vii.

[2] *Essay*, b. i., chaps. ii., iii., iv.; b. ii., chap. ii.

[3] For the history of the doctrine of mental association, on which our limits will not allow us to enter, the reader is referred once for all to the admirable note of Sir William Hamilton, *Reid's Works*, p. 889. The illustrious writer has triumphantly vindicated the claims of Aristotle to be regarded as the earliest, and, even to this day, the most accurate and complete expositor of the whole theory, and has supplied some interesting facts in its later history from authors almost unknown to ordinary readers.

[4] See the criticisms of Reid, *Intellectual Powers*, Essay iv., chap. iv.; of Sir James Mackintosh, *Dissertation* (*ante*, vol. i., p. 381); and of Sir William Hamilton, *Reid's Works*, p. 907.

[5] *Reid's Works*, p. 911.

Hamilton observes, it is improper to say of such terms that they are *associated* or mutually *suggestive*, since the thought of both is already given in the thought of each.

These being discarded, there remain to be considered those relations of thought which, in the language of Sir W. Hamilton, are distinguished as indicating a *psychological* or *subjective* consecution,—a connection, that is to say, established between two phenomena of consciousness, owing to some accidental juxtaposition in the mind of the person connecting them. Phenomena of this class belong entirely to the reproductive or representative consciousness; for, though the suggesting antecedent may be an intuition presented from without, the suggested consequent, not being given with it, is called up by the action of the mind itself; and thus the connection between the two is an act of representation or thought. The phenomena of association, in this limited sense, may be comprehended under two principal classes:—1. Those of direct remembrance or memory, in which the occurrence of any mode of consciousness at a certain time suggests the fact of the same mode having been experienced at a previous time. 2. Those of indirect remembrance or reminiscence, in which the occurrence of any mode of consciousness at a particular time suggests the recollection of a different mode of consciousness, which at some previous time was experienced along with it. Hence arise the two general laws, distinguished by Sir W. Hamilton[1] as those of repetition and redintegration; namely, *Thoughts coidentical in modification, but differing in time, tend to suggest each other*: and, *Thoughts once coidentical in time, are, however different as mental modes, again suggestive of each other, and that in the mutual order which they originally held.* The first of these laws must be extended to include not merely total identity of the mental modification, but also that partial identity which is the basis of resemblance or analogy. Thus, for example, I may see a man, and recognise him as the same person whom I met a few days ago. Here there is a complete identity of two mental modifications, differing only in point of time, as earlier and later. But again, I may see, not the man himself, but his portrait; and this may remind me of the original. Here there is a partial identity of the mental modifications; the man and the picture being in certain features the same, however different in other respects. Or again, the metaphorical use of the term *man*, as applied to the figures on a chess-board, or to the cairn on the top of a mountain, may suggest the object from which the metaphor was derived. Here, however little there may be of visible resemblance between the objects, there is still one point in which they are identical, namely, that both are denoted by the same word.[2] The second law is of still wider application. Not only homogeneous modes of consciousness, —two cognitions, two feelings, two desires,—but heterogeneous modes,—a cognition and a feeling, or a feeling and a desire, which have at any past time been associated together,—may on future occasions mutually suggest each other. The sight of a place may recal to mind an event which has taken place there, and the feeling of joy or sorrow which that event occasioned to ourselves.[3] The sight of the surgeon who has performed a painful operation upon us may recal vividly an image of the agony which we suffered at his hands, and create a feeling of dislike at his presence.[4] The food which we have tasted during illness, or the syrup in which a bitter medicine was administered, may ever afterwards convey to the mind an impression, in some cases almost amounting to an actual repetition, of the suffering which we felt, or the bitterness which we tasted.[5]

But the above laws, being the most universal principles of association in general, are not sufficient to account for the special instances included under each. They explain why certain associations of ideas *may* take place; but they do not tell us why this particular association actually takes place in preference to others of the same kind. Any two modes of consciousness which have once been coexistent in experience have a tendency to suggest one another; but this does not explain why the tendency is realized in certain instances and not in others. To account for these special phenomena, we must have recourse to a third law,—that of preference. *Thoughts are suggested, not merely by force of the general subjective relation subsisting between themselves; they are also suggested in proportion to the relation of interest (from whatever source) in which these stand to the individual mind.*[6] The grounds of this predominant interest may be of various kinds. Sometimes the frequent occurrence of certain experiences may impress the association which they convey indelibly on the mind, and serve to recal it on the slightest occasion. At other times the intensity of the feeling connected with the occurence may atone for its comparative rarity, and an event which has occurred but once in a lifetime may haunt the memory incessantly during the remainder of our existence. In some instances, in which the repetition is frequent and the suggested consequent of greater practical importance than the antecedent which suggested it, the latter disappears entirely from the consciousness, and the result of association becomes transformed apparently into that of immediate apprehension. A striking instance is furnished by those phenomena of the senses which have been already described under the name of Acquired Perceptions; such as the apprehension of the distance and unity of objects by the eye, in which the immediate and proper objects of sight, the rays in contact with the two retinæ, have been dropped out of consciousness, and the distant luminous body is to all appearance directly visible. Something similar to this may be observed in less familiar instances, in which we are conscious of the existence of a train of suggested thoughts remotely connected with each other, but overlook the intermediate and less important links. Such for example, is the often-quoted instance mentioned by Hobbes.[1] "In a discourse of our present civil war, what could seem more impertinent than to ask, as one did, what was the value of a Roman penny? Yet the coherence to me was manifest enough. For the thought of the war introduced the thought of the delivering up the king to his enemies; the thought of that brought in the thought of the delivering up of Christ; and that again the thought of the thirty pence which was the price of that treason." It is probable, as Stewart has remarked upon this passage,[2] that had the speaker himself been interrogated about the connection of his ideas, he would have found himself at first at a loss for an answer.

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[1] *Reid's Works*, p. 912. The latter of these laws has been usually regarded by modern philosophers as the sole general law of association. See, for example, Hobbes, *Leviathan*, chap. iii.; Leibnitz, *Nouveaux Essais*, l. ii., chap. xxxiii.; Mill, *Analysis of the Human Mind*, chap. iii. The former law may perhaps have been hinted at by Aristotle, but its distinct recognition and enunciation are due to Sir W. Hamilton.

[2] In some cases the association may depend on mere identity of name, without any other point of similarity or analogy. Thus Alexander the Great may suggest Alexander the Coppersmith. On the influence of language as a principle of association, see Hobbes, *Human Nature*, chap. v.; Stewart, *Elements*, chap. v., part. i., sect. 2.; Mill, *Analysis of the Human Mind*, chap. iii. Not only identity of names, but even of letters, is noticed by Stewart, as in the case of ideas in poetry suggested by alliteration.

[3] This is beautifully described by Shelley in a passage from which we can only quote a small portion:—

"You are not here! the quaint witch Memory sees
In vacant chairs your absent images,
And points where once you sat, and now should be,
But are not.—I demand if ever we
Shall meet as then we met;—and she replies,
Veiling in awe her second-sighted eyes,—
'I know the past alone—but summon home
My sister Hope, she speaks of all to come.'
But I, an old diviner, who know well
Every false verse of that sweet oracle,
Turned to the sad enchantress once again,
And sought a respite from my gentle pain,
In acting every passage o'er and o'er
Of our communion."

[4] See the anecdote narrated by Locke, *Essay*, b. ii., chap. xxxiii., sect. 14.

[5] See the instance mentioned by Vives, quoted by Sir W. Hamilton, *Reid's Works*, p. 893.

[6] Sir W. Hamilton, *Reid's Works*, p. 913.

The three above-mentioned laws, of repetition, redintegration, and preference, will, in many cases, act in combination with each other; ideas, once associated by similarity, being afterwards farther connected by the fact of that juxtaposition, and acquiring a preferential claim by the frequency of the recurrence. Thus the sight of the picture of a man may suggest the original; and afterwards the thought of the man may suggest the thought of his picture, as having been seen at a former time in connection with it. Here the elements of similarity and diversity are combined together in the same association, as identical modifications of thought at diverse times, and again as diverse modifications of thought at the same time.[3] To the two first laws may also be reduced the four heads of association enumerated by Aristotle; viz., Proximity in Time, Similarity, Contrast, and Coadjacence.[4]

The phenomena of mental association, if in modern times they have been too much neglected by some philosophers, have unquestionably been exalted to an extravagant degree of importance by others. If Locke, on the one hand, appeals to this principle chiefly to explain some extravagances and prejudices of individual minds, later writers have, on the other hand, made far more than sufficient amends, by attributing to the power of association results which it is utterly incapable of producing or explaining. According to Hartley and his follower Priestley, "Not only all our intellectual pleasures and pains, but all the phenomena of memory, imagination, volition, reasoning, and every other mental affection and operation, are only different modes or cases of the association of ideas; so that nothing is requisite to make any man whatever he is, but a sentient principle, with this single property."[5] In a like spirit, Sir James Mackintosh, in language in which some allowance must perhaps be made for the rhetoric of a public lecture, affirmed that the law of association was the basis of all true psychology; and that Hartley, by his exposition of this principle, stood in the same relation to Hobbes as Newton to Kepler; the law of association being that to the mind which gravitation is to matter.[6] Condillac, a few years before Hartley, had testified to the same effect, asserting that all the operations of the mind are engendered from perception alone, and that the investigation of this process was of more value than all the rules of the logicians.[7] Accordingly, in Hartley's theory, as well as in that of Condillac, not only our desires and affections, and the phenomena of memory and imagination, but even the universal laws of thought, and the necessary principles of mathematical reasoning, and the immutable judgments of the moral faculty, and the self-determinations of the will, are derived with equal readiness from this prolific law acting on the material furnished by the senses. Association in psychology becomes, like the adverb in grammar, entitled to the appellation of the universal recipient, in which is swallowed up every mode of consciousness, and every faculty of the mind.[8] That the foundation is not always able to bear the weight of superstructure placed upon it, may be suspected at the outset from the amount of transformation which, in the systems of Condillac and Hartley, the sensible materials have to undergo, during the process of association, and of association only. Like "compound medicines," to use the simile of Hartley himself, "the several tastes and flavours of the separate ingredients are lost and overpowered by the complex one of the whole mass; so that this has a taste and flavour of its own, which appears to be simple and original, and like that of a natural body."[9] Thus the sensation of bodily pain becomes by association the emotion of fear; the pleasure of sucking, and other sensible enjoyments bestowed by the same person, become the affection of the child for its mother; and the restraint imposed upon actions by prohibition and punishment is gradually metamorphosed into the ideas of right, wrong, and obligation. The advocates of this kind of mental chemistry appear to have overlooked the fact that ideas have not, like chemical substances, a distinct existence and properties of their own, but exist and operate only as modes of the conscious mind. Consequently, the changes effected, even granting in all cases the assumed affiliation of consequent on antecedent, must be due to a transforming power or natural faculty of the mind itself, not to a mere working of sensible impressions in combination with each other. But this admission amounts to a confession that sensation is not the source of the derived ideas, but only furnishes the occasion on which the mind exercises a power of its own, thereby framing additional ideas, or elements of ideas, which sensation does not contain and cannot supply. To this it must be added, that the power of associating ideas at all implies a consciousness of their difference from, and mutual relation to, each other; and that thus association presupposes thought, instead of thought being the offspring of association.[10] But the failure of Hartley's theory is most conspicuous in reference to the phenomenon which we have next to consider,—the existence, namely, in consciousness of *necessary truths.*

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[1] *Leviathan*, part i., chap. iii.

[2] *Elements*, part ii., chap. ii.

[3] An ingenious, though quaint illustration of this is given by Coleridge, *Biographia Literaria*, chap. vii.:—"Seeing a mackerel, it may happen that I immediately think of gooseberries, because I at the same time ate mackerel with gooseberries as the sauce. The first syllable of the latter word being that which had coexisted with the image of the bird so called, I may then think of a goose. In the next moment the image of a swan may arise before me, though I had never seen the two birds together. In the first two instances, I am conscious that their coexistence in time was the circumstance that enabled me to recollect them; and equally conscious am I that the latter was recalled to me by the joint operation of likeness and contrast. So it is with cause and effect; so too with order."

[4] See Sir W. Hamilton's note, *Reid's Works*, p. 899, where the classification of Aristotle is examined and compared with those of Hume and others.

[5] See Priestley, *Hartley's Theory*, Introductory Essays, p. xxiv.

[6] Lecture delivered at Lincoln's Inn; quoted by Coleridge, *Biographia Literaria*, chap. v. In his Preliminary Dissertation, *ante*, vol. i., p. 378, Sir James's judgment of Hartley is more discriminating.

[7] *Origine des Connoissances Humaines*, section seconde. This work was published about three years before Hartley's *Observations on Man*. The theory of the latter, however, seems to have been formed independently, and is far more complete and elaborate, as regards association, than that of the former. Some remarks in comparison of the two will be found in Sir James Mackintosh's Dissertation, *ante*, vol i., p. 380.

[8] "Adverbium Stoici πανδέκτην vocant; nam omnia in se capit, quasi collata per satyram concessa sibi rerum varia potestate." *Charisii Ars Grammatica*, lib. ii., De Adverbio.

[9] Hartley, *Observations on Man*, prop. xii., cor. 1.

[10] In the above remarks we have considered Hartley's system only with reference to the doctrine of association, omitting the mechanical hypothesis of vibrations, on which that doctrine is founded. A valuable criticism of the whole theory will be found in Coleridge's *Biographia Literaria* chaps. vi. and vii.

OF NECESSARY TRUTHS.

It is a fact of consciousness to which all experience bears witness, and which it is the duty of the philosopher to admit and account for, instead of disguising or mutilating it to suit the demands of a system, that there are certain truths which, when once acquired, no matter how, it is impossible, by any effort of thought, to conceive as reversed or reversible. Such, to take the simplest instances, are the truths of arithmetic and geometry. By no possible effort of thought can we conceive that twice two can make any other number than four, or that two straight lines can inclose a space, or that the angles of a triangle can be greater or less than two right angles; nor yet can we conceive it possible that, by any future change in the constitution of things, even by an exertion of Omnipotence, these facts can hereafter become other than they are, or that they are otherwise in any remote part of the universe. It is this characteristic of a certain class of judgments, which the theory of association altogether fails to explain; for it does not appear in those instances in which, according to that theory, we ought to expect it. Probably no man, even of those acquainted with geometry, reads Euclid every day; and many pass several days together without thinking of mathematical relations at all. Consequently, the conviction that day and night must succeed one another once in every twenty-four hours, ought, as far as it depends on association, to be more fixed and certain than that the angles of a triangle are equal to two right angles, or that seventeen and eight make twenty-five. Whereas, in point of fact, while the two latter propositions are conceived as possessing an eternal and absolute necessity, which no exertion of power can change,[1] the former is regarded as one out of many possible arrangements, which has no other necessity than the will of the Creator, which might be changed at any moment by an exertion of the same will that produced it, which does not hold good in other parts of the universe, nor even in certain regions of our own globe. Again, on the theory of association, our conviction of the truth of mathematical propositions should be more certain in proportion to the number of instances in which we have seen them verified. That two and two make four, or that two straight lines do not inclose a space, should be admitted at first with doubt and hesitation, and asserted with more confidence as our experience of its truth increases. Here, again, the fact is at variance with the theory. A single enunciation of an axiom, or a single demonstration of a theorem, in mathematics, is as valid as a thousand; and the conviction once gained is gained with an absolute certainty which no subsequent evidence can increase.

The judgments which appear to possess this character of absolute necessity in thought, which no theory of mere association can explain, may be classified under the following four heads.—1. Logical judgments, in which the predicate is identical with the whole or a part of the attributes comprehended in the subject; as that every triangle must have three angles, that the sums of equal things must themselves be equal, or that all men must be animals. 2. Mathematical judgments, which express a necessary relation between two distinct notions concerning quantity, continuous or discrete; as that two straight lines cannot inclose a space, that the angles of every triangle must be equal to two right angles, or that seven and five must make twelve. 3. Moral judgments, which state the immutable obligation of certain laws of conduct, whether actually observed in practice or not; as that ingratitude or treachery must at all times and in all persons be worthy of condemnation. 4. Metaphysical judgments, expressing an apparently necessary relation between the known and the unknown, between the sensible phenomenon and the supersensible reality; as that every attribute belongs to some substance, and that every change is brought about by some cause. The necessity in all these four classes of judgments is essentially different from that manifestation of the laws of nature which is sometimes distinguished by the name of physical necessity. The laws of nature, if by *nature* is meant unconscious agents only, express nothing more than an observed fact in its highest generalization; and of that fact we can only say that it is so, and that it might have been otherwise. This is the case even with those phenomena whose relations may be exhibited by mathematical formulæ; for though the mathematical portion of the reasoning may have an *à priori* necessity, its application to the facts in question is empirical, and, as far as thought is concerned, contingent. Thus, that a body in motion, attracted by a force varying inversely as the square of the distance, will describe a conic section, is a matter of demonstration; but that the earth is such a body, acted upon by forces of this description, is a matter of fact, which might have been otherwise, had the Creator been pleased so to appoint. Necessity is the result of law; and law implies an agent whose working is regulated thereby.[2] But it is a law only to that which works under it; to an observer, who sees the results of the law without being subject to its influence, it is no more than a fact of experience. The laws of nature may be a sufficient reason why certain phenomena must take place in a certain way; but they furnish no reason at all why I must think so. As it is optional with me to study the phenomena in question, it is optional with me to become acquainted with their laws; and I can become acquainted with them as facts only. To know a law as such, I must know it as an obligation binding upon myself as a thinker; and this alone can give rise to a necessity of thought. When I speak of the alternations of day and night as consequent on a *law* of nature, I mean no more than that the alternations have invariably been observed to take place; and when I resolve such alternations into the *law* of the earth's rotation, I mean only that the earth does revolve on her axis once in twenty-four hours. *My belief* in the continuance of the observed order of natural phenomena may perhaps be explained by some law of my mental constitution; but, as thus explained, it is a law of mind and not of matter.

Of the four classes of judgments above distinguished as necessary in thought, the first, or logical judgments, do not require much explanation. Any notion, however, empirical in its origin, must, when once acquired, be analysed in accordance with the general laws of thought; and the result will exhibit that formal necessity which implies no more than the harmony of a thought with itself. Judgments of this character, affirmative and negative, are only particular instances of the two great laws of identity and contradiction, and have been already sufficiently explained in our previous remarks on the operations and laws of thought. Thus the axiom, that the sums of equal things are equal, may be expressed, representing the first pair of equals by A, and the second by B, in the form of the identical judgment, $A+B=A+B$. The analysis of a complex notion into its constituent parts, as in the assertion that all men are animals, or that every triangle has three angles, is only a special application of the identical judgment "A is A;" or, "any particular specimen of a class has the general attributes of the class to which it belongs."

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[1] Le Clerc (*Logica*, p. ii., cap. iii.) enters into a defence of the canons of logic against certain theologians who maintained that the Divine power could make two contradictory judgments simultaneously true. But even this intrepid assertion of apparent absurdity does not amount to maintaining that *we can conceive* such an exertion of power; and this is all with which, as psychologists, we are concerned.

[2] "All things that are have some operation not violent or casual. That which doth assign unto each thing the kind, that which doth moderate the force and power, that which doth appoint the form and measure, of working, the same we term a law." (Hooker, *E. P.* i. 2.)

Mathematical judgments may be divided into two kinds,—indemonstrable or axiomatic judgments, whose necessity is self-evident; and demonstrable judgments, whose necessity depends on some previous assumption. The necessity of the latter is derived from that of the former, so that the indemonstrable judgments alone require a special examination. Under this class are comprehended the axioms of geometry, properly so called;[1] viz., the original assumptions concerning magnitudes in space as such, and the propositions belonging to the fundamental operations of arithmetic,—addition, and subtraction.[2] The necessity of these judgments results from the existence in the mind of the *à priori* forms of intuition,—space and time. The axioms of geometry are self-evident statements concerning magnitudes in space; such as that two straight lines cannot inclose a space. Their self-evidence or necessity is to be explained by the circumstance that the presented intuition, as well as the representative thought, is derived from within, not from without. For geometrical propositions are primarily necessary, not as truths relating to objects without the mind, but as thoughts relating to objects within; their necessity, as regards real objects, is only secondary and hypothetical. If there exist anywhere in the world two perfect straight lines, those lines cannot inclose a space; but if such lines exist nowhere but in my imagination, it is equally true that I cannot think of them as invested with the contrary attribute. This necessity of thought is dependent on a corresponding necessity of intuition. The object of which pure geometry treats is not dependent on sensation, but sensation on it: it is a condition under which alone sensible experience is possible; and therefore its characteristics must accompany all our thoughts concerning any possible object of such experience; for, however much we may abstract from the attributes of this or that particular phenomenon of experience, we are clearly incompetent to deprive it of those conditions under which alone, from the constitution of our minds, experience itself is possible. We can perceive only as we are permitted by the laws of our perceptive faculties, as we can think only in accordance with the laws of the understanding. If, then, by a law of my perceptive faculty, I am compelled to regard all objects as existing in space, the attributes which are once presented to me as the properties of a given portion of space, such as the pair of straight lines now present to my sight or imagination, must necessarily be thought as existing in all space and at all times. For to imagine a portion of space in which such properties are not found, would not be to imagine merely a different combination of sensible phenomena, such as continually takes place without any change in the laws of sensibility:—it would be to imagine myself as perceiving under other conditions than those to which, by a law of my being, I am subjected. But a condition, though potentially existing in the original constitution of the mind, is actually manifested only in conjunction with that of which it is the condition. Space, therefore, and its laws are first made known to consciousness on the occasion of an actual phenomenon of sense. Hence the twofold character of geometrical principles: empirical, as suggested in and through an act of experience; necessary, as relating to the conditions under which alone such experience is possible to human faculties.

Arithmetic is related to time as geometry to space, and the necessity of its propositions may be explained upon similar principles. The two sciences, however, present some important features of distinction. Most of the propositions of geometry are deductive: it contains very few axioms, properly so called, and its processes consist in the demonstration of a multitude of dependent propositions from the combination of these axioms with certain logical principles of thought in general. On the other hand, the fundamental operations of arithmetic,—addition and subtraction,—present to us a vast number of independent judgments, every one of which is derived immediately from intuition, and cannot, by any reasoning process, be deduced from any of the preceding ones.[3] Pure geometry cannot advance a step without demonstration, and its processes are therefore all reducible to the syllogistic form. Pure arithmetic contains no demonstration; and it is only when its calculus is applied to the solution of particular problems that reasoning takes place, and the laws of the syllogism become applicable. It is not reasoning which tells us that two and two make four; nor, when we have gained this proposition, can we in any way deduce from it that two and four make six. We must have recourse, in each separate case, to the senses or the imagination, and by counting up an individual succession corresponding to each term, intuitively perceive the resulting sum. The intuition thus serves nearly the same purpose as the figure in a geometrical demonstration; with the exception that, in the latter case, the construction is adopted to furnish premises to a proposed conclusion; while in the former, it gives us a judgment which we have no immediate intention of applying to any further use.

The intuition in the case of arithmetic is furnished by the consciousness of successive states of our own mind. Setting aside all other characteristics of those states, save that of their succession in time, we have the immediate consciousness of *one*, *two*, *three*, *four*, &c. A purely natural arithmetic would consist in carrying on this series, with no other relation between its members but that of succession, until the memory became unable to continue the process. The artificial methods by which calculation is facilitated and extended, such as that of a scale of notation, in which the series recommences after a certain number of members, vastly increase the utility of the calculus, but do not affect its psychological basis. To construct the science of arithmetic in all its essential features, it is only necessary that we should be conscious of a succession in time, and should be able to give names to the several members of the series; and since in every act of consciousness we are subject to the condition of succession, it is impossible in any form of consciousness to represent to ourselves the facts of arithmetic as other than they are.

The necessity of propositions in geometry and arithmetic is thus derived from their relation to the universal forms of intuition, space, and time. We can suppose the possibility of beings existing, whose consciousness has no relation to space or time at all. This is no more than to admit the possible existence of intelligent beings otherwise constituted than ourselves, and consequently incomprehensible by us. But to suppose the existence of geometrical figures or arithmetical numbers such as those with which we are now acquainted, is to suppose the existence of space and time as we are now conscious of them, and therefore relatively to beings whose mental constitution is so far similar to our own. Such a supposition necessarily carries with it all the mathematical relations in which space and time, as given to us, are necessarily thought. For mathematical judgments strictly relate only to objects of thought as existing in my mind, not to distinct realities existing in relation to my mind. They therefore imply no other existence than that of a thinking subject, modified in a certain manner. Destroy this subject, or change its modification, and we cannot say, as in other cases, that the object may possibly exist still without the subject, or may exist in a new relation to a new subject; for the object exists only in and through that particular modification of the subject, and, on any other supposition, is annihilated altogether. Thus it is impossible to suppose that a triangle can, in relation to any intelligence whatever, have more or less than two right angles, or that two and two should not be equal to four; though it is quite possible to suppose the existence of intelligent beings destitute of the idea of a triangle or of the number two. This is *necessary matter* in the strict sense of the term; a relation which our minds are incapable of reversing, not merely positively, in our own acts of thought, but also negatively, by supposing others who can do so.

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[1] Under this head are included the tenth, eleventh, and twelfth *axioms*, as they are called in the modern editions of Euclid (*postulates* is Euclid's own term), with several other geometrical assumptions employed in the subsequent demonstrations, though not distinctly expressed. The remaining *axioms* of the modern editions (the *common notions* of Euclid himself) are logical, not geometrical principles, and depend solely on the laws of thought.

[2] "Though in some things, as in numbers, besides adding and subtracting, men name other operations, as *multiplying* and *dividing*, yet are they the same; for multiplication is but adding together of things equal; and division but subtracting of one thing as often as we can." (Hobbes, *Leviathan*, p. i., chap. v.)

[3] Subtraction may be demonstrated from addition, if all the results of the latter are supposed to be given, or *vice versa*; though it is simpler to regard subtraction as an independent process of *denumeration*, as is done by Condillac, *Langue des Calculs*, chap. i. But no result of either can be derived from a preceding result of the same operation.

A somewhat similar consideration will explain the necessity of moral judgments also. The fact of duty, whether in conformity or not with an absolute standard of morality, is in each case intuitively presented to me as an act in relation to a law of whose obligation on myself I am immediately conscious. It thus essentially differs from the phenomena of external nature, whose laws I do not intuitively perceive, but only infer them from the observed recurrence of certain facts. The moral sense, like the intuitions of space and time, is thus an *à priori* condition of my mind, not determined by experience as it is, but determining beforehand what experience ought to be; and, though manifested in consciousness on the occasion of experience, does not arise from experience as a fact, but is given by nature as a law, which, like other natural gifts, grows with our growth, and develops itself in a certain way, whatever may be the experience to which it is subjected. Its nature, like that of the tree, cannot be changed by the soil in which it is planted, though its growth may be advanced or stunted by this or other accidental circumstances.[1] But the immediate consciousness of law carries with it a consciousness of necessity and immutability in relation to the agent who is subject to it. For to suppose the law reversed in relation to myself, to suppose that it can ever become *my duty* to do what it is now my duty to forbear, is to suppose my whole mental constitution to be reversed, my personality still remaining unchanged;—a supposition which destroys itself; since my present mental constitution is included in the idea of my personality. Hence I cannot conceive myself as subjected to a different law of moral obligation from that of which I am conscious; nor yet can I conceive other beings so subjected; for I can only conceive their obligations at all by regarding their mental constitution in this respect as identical with my own. But I have no difficulty in supposing the existence of creatures who have no conception of duty at all (though even in this case I cannot distinctly conceive the nature of their consciousness); just as I can suppose the existence of creatures who have no conception of mathematical relations; and such a supposition is indeed actually made with regard to the lower animals. This explanation is sufficient to account for the necessary character of morality, regarded as a subjective obligation of the personal conscience. Its objective character, as indicating a standard above conscience, belongs to another branch of metaphysical inquiry.

The principles of substance and causality likewise depend, for their necessity as thoughts, on a previous necessity of intuition; but, in relation to both, it is requisite to distinguish between the necessary thought itself and the accidental associations by which it is accompanied. As regards material substances, for example, what do we mean when we say that extension, figure, colour, hardness, &c., are the attributes of *something* extended, figured, coloured, hard, &c.? Are we compelled to think that, besides the sensible qualities, there exists a distinct imperceptible thing to which those qualities belong; or can the language which apparently conveys this meaning be explained in any other sense? We are not now inquiring into the real existence of this supposed substratum; which is a question of ontology, not of psychology: we are only asking, Do we, as a mental fact, really suppose it to exist; and, if so, how can that supposition be accounted for? Are we, as a matter of fact, compelled to think that, besides the properties which we perceive by the senses, there exists also an insensible substratum, in which they inhere, to use the simile of Coleridge,[2] like pins sticking in a pin-cushion and hiding it? Consciousness surely tells us nothing of the kind; but what it does tell us is sufficient to explain how its testimony has been thus perverted. In the first place, it tells us that no sensible quality can be perceived or conceived by itself; but that each is necessarily accompanied by an intellectual apprehension of its relations to space, as occupying it and contained in it. Colour cannot be perceived without extension; nor extension without solidity; and solidity is not a single attribute, but includes in its comprehension the three spacial dimensions of length, breadth, and thickness. In the second place, it tells us that all sensitive perception is a relation between self and not-self; that all sensible objects are apprehended as occupying space, and thus as distinct from the apprehending mind, whether distinct or not from the bodily organism. Every attribute is thus intuitively perceived, and consequently is also reflectively conceived, as accompanied by other attributes, and as constituting, in conjunction with those attributes, a *non-ego* or sensible thing: but of an insensible substratum consciousness tells us, and can tell us, nothing; nor do we feel any necessity of believing in its existence, when the question is distinctly put before us, disentangled from its usual associations.

But does not the use of language, it may be asked, imply a real, though perhaps a confused consciousness of something more than this? Does not the name of each attribute separately denote relation, not merely to other attributes, but to a substance? Does not extension imply a thing extended, and colour a thing coloured, not merely a coloured extension or an extended colour? What, in short, is the difference denoted by the use of abstract and concrete terms, except that qualities are universally apprehended as really inhering in a subject, though logically distinguishable from it? An explanation of this may, we think, be furnished, partly by a fact of the sensitive consciousness, and partly by an association derived from another source. The fact is to be found in the distinction which has been pointed out in the preceding pages between sensation and perception. Any material phenomenon may be regarded in two points of view: First, by itself, as a particular affection of the nervous organism, distinguishable as such from any other, and present to consciousness as a mode of the sentient subject. Secondly, in conjunction with the apprehension of space, as extended, consisting of parts out of each other, and constituting one element of the complex phenomenon which is conceived as an object. The former point of view is indicated by the abstract, the latter by the concrete term. In the former we contemplate the sensible affection alone, as a state of the *ego*, without attending to the necessary accompaniment of its relation to space. In the latter we contemplate it in the opposite relation, as forming one element of the material *non-ego*, or sensible object existing in space. The association which has contributed to a different interpretation of these terms is furnished by the opposite class of intuitions, those, namely, of internal perception or self-consciousness. Modes of mind differ from modes of body, in being immediately given in relation to a common subject. While colour, and figure, and hardness, and other sensible qualities, are united together only by their coexistence in space, sensations, emotions, volitions, and other affections of mind are manifested in consciousness as modes of existence of one and the same indivisible self,—the subject of all, and yet identical with none. The personal self is neither a mode of consciousness nor the aggregate of many modes, but a substance, distinct from all its affections, though discerned in consciousness in conjunction with them. This one presented substance, *myself*, is the basis of the other notions of substance which are thought representatively in relation to other phenomena.[1] When I look at another man, I do not immediately perceive his consciousness; but I can mediately and reflectively transfer to another that of which I am directly cognisant only in myself. Beyond the class of conscious beings, I have only a negative idea of substantiality, except in so far as it is synonymous with the occupation of space.[2] Some imperceptible bond of union between the phenomena of matter may exist, or it may not; but if it does exist, it exists in a manner of which I can form no conception; and if it does not exist, my faculties do not enable me to detect its absence. But the immediate knowledge, which consciousness gives me, of my own presented unity, is sufficient to explain the association which has led to its representation in other objects.

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[1] Arist. *Eth. Nic.* vi., 11. Διὸ καὶ φυσικὰ δοκεῖ εἶναι ταῦτα, καὶ φύσει σοφὸς μὲν οὐδείς, γνώμην δ᾽ ἔχειν καὶ σύνεσιν καὶ νοῦν. Σημεῖον δ᾽ ὅτι καὶ ταῖς ἡλικίαις οἰόμεθα ἀκολουθεῖν, καὶ ἥδε ἡ ἡλικιά νοῦν ἔχει καὶ γνώμην, ὡς τῆς φύσεως αἰτίας οὔσης.

[2] *Aids to Reflection*, Conclusion.

The principle of causality, as well as that of substance, has been disguised by associations which do not properly belong to it. In the first place, we must separate the special judgment from the general;—the assertion that this particular event is dependent on this particular cause, from the assertion that every event is dependent on some cause. The belief in the uniformity of nature is not a necessary truth, however constantly guaranteed by our actual experience. We are not compelled to believe that, because A is ascertained to be the cause of B at a particular time, whatever may be meant by that relation, A must therefore inevitably be the cause of B on all future occasions. This conviction may amount to a moral certainty; we may act upon it without hesitation in the affairs of life; but it has no such necessity that we are unable to conceive the contradictory.[3] But to conceive it possible that B may at one time be caused by A and at another by C, and that A may at one time produce the effect B and at another D, the other circumstances being in all the cases exactly alike, is very different from conceiving it possible that B may exist without being produced by any cause, and that A may exist without producing any effect. In the second place, therefore, we must ask what is the exact meaning of the assertion, that every event must be produced by *some cause*. In one sense, this judgment is unquestionably necessary. If *cause* be interpreted to mean no more than *temporal antecedent*, the assertion that every event must have a cause implies only that no event can be conceived as the beginning of all existence, but that in every case we are compelled to think that it has been preceded by some other. This is the necessary consequence of the subjection of our intuitions to the law of time. I can be conscious of an event only as taking place in time, and I can be conscious of time only in conjunction with a succession of events taking place in it. It is therefore impossible to conceive an absolutely first occurrence. The principle of causality is thus derived from the intuition of time, as that of substance is from space. To this necessary notion of *some antecedent* is afterwards united by association the empirical notion of the uniformity of nature; and the conception of cause thus assumes the form in which Hume and Brown, from different points of view, both regard it; namely, that of the invariable antecedent of a particular change. The law of time compels us to believe that there *must be* some antecedent phenomenon or aggregate of phenomena; experience, and the anticipations to which experience gives rise, tell us that this antecedent *is* invariable; and the complex judgment is apparently invested with the absolute necessity which of right belongs to one of its ingredients only.

But the causal judgment, as usually understood, appears to contain something more than the idea of antecedence. The cause is supposed, not merely to precede the effect, but to have *power* to produce it. Whether the notion of *invariable recurrence* is included or not, it seems at least to be regarded as certain that, *upon any one occasion*, the effect is so far completely dependent upon the cause, that, the latter being given, the former *cannot but* take place. The explanation of this impression may, we think, be found in another association, derived from the personal causality manifested in volition. In the exercise of an act of will, I am intuitively conscious of two things:—First, that I am acted upon, though not necessitated by, motives: secondly, that I act upon my own determinations as their producing cause. In the first relation I am conscious of a choice between two alternatives; that is to say, that from certain given antecedent motives, a particular consequent may or may not follow, as I choose to determine. In the second relation I am conscious of an exercise of power;[4] the final determination being called into existence by an act of my own will. To this intuition may be traced the origin of the idea of power and of causation, in a sense distinct from that of mere temporal antecedence. The power of which I am presentatively conscious in myself, I transfer representatively to other agents whom I suppose to be similarly constituted to myself; and thus I regard other men as being, like myself, the efficient causes of their own determinations, and, through their determinations, of their actions. But beyond the range of conscious beings, this representation of cause, like the corresponding one of substance, is inadmissible. The connection between the antecedent motive and the consequent determination is regarded as contingent, so long as a voluntary exercise of power is interposed between the two. But where consciousness, and consequently volition, is excluded, I can no longer regard the relation between the antecedent and consequent phenomenon as contingent. Contingence in a single succession[1] is only conceivable under the form of *choice*, by the interposition of the *ego*, the only given substance, between two successive phenomena. When this is excluded, the phenomena become co-adjacent; there is no choice, and consequently no conceivable contingence in the succession. The apparent necessity of the causal relation in every single instance is thus explicable as a negative idea. It is not so much a positive conception of necessity, as an inability to conceive the opposite. But this inability does not depend on a law of thought. It is not an essential, but an accidental inconceivability, dependent, according to the classification made in a previous page,[2] on a defect in the matter of intuition. The contingency is in this case inconceivable, because contingency can only be conceived at all in the form in which alone it is presented to intuition, namely, as a conscious choice between two alternatives.[3] If this explanation of the apparent necessity of the causal judgment be admissible, it will lead to some important consequences as regards the question of free will and determinism. But this controversy belongs rather to ontology than to psychology.

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[1] "Ex iis vero quæ in ideis rerum corporalium clara et distincta sunt, quædam ab idea mei ipsius videor mutuari potuisse; nempe *substantiam*, durationem, numerum, et si quæ alia sint ejusmodi." (Descartes, *Meditatio Tertia.*) From this was probably borrowed the similar remark of M. Royer-Collard (see Jouffroy's translation of Reid, vol. iv., p. 350):—"Le moi est las eule unité qui nous soit donnée immédiatement par la nature; nous ne la rencontrons dans aucune des choses que nos facultés observent. Mais l'entendement, qui la trouve en lui, la met hors de lui par induction, et d'un certain nombre de choses coexistantes il crée des unités artificielles."

[2] Una est cujusque substantiæ præcipua proprietas, quæ ipsius naturam essentiamque constituit, et ad quam aliæ omnes referuntur. Nempe extensio in longum, latum et profundum substantiæ corporeæ naturam constituit; et cogitatio constituit naturam substantiæ cogitantis. Nam omne aliud quod corpori tribui potest, extensionem præsupponit, estque tantum modus quidam rei extensæ; ut et omnia, quæ in mente reperimus, sunt tantum diversi modi cogitandi." (Descartes, *Principia*, i. 53.)

[3] Into the controversies concerning the origin of this belief it is unnecessary to enter. Whether it be derived from association, or from an intuitive law of the mind, or from any other source,—whether it be conceived as absolutely certain, so long as the present constitution of the world lasts or not,—is immaterial. At any rate, it is not conceived as a law which in no imaginable world, and by no possible exertion of power, could be otherwise than it is: and this is sufficient to exclude it from the class of necessary truths which we are now considering.

[4] Those philosophers who derive the idea of causation exclusively from the succession of phenomena, are bound in consistency to re-

The above inquiry into the nature and origin of necessary truths will enable us to throw some light on the controverted question concerning the existence of innate ideas, —a question which should be discussed, not where Locke placed it, at the beginning of mental philosophy, but at the end; for its answer depends on an examination of the actual features of the phenomena of consciousness, and thus presupposes the facts of psychology, instead of being presupposed by them. Setting aside, as irrelevant, those arguments which are little better than quibbles on the word *innate*, such as Locke's appeal to the consciousness of newborn children, the real point to be determined is this:—Are there any modes of human consciousness which are derived, not from the accidental experience of the individual man, but from the essential constitution of the human mind in general, and which thus naturally and necessarily grow up in all men, whatever may be the varieties of their several experiences?[4] The previous analysis of consciousness will furnish an answer to this question. Every phenomenon of consciousness consists of two elements,—a matter, derived from experience; and a form, dependent on the original constitution of the mind. But the matter and the form are given in conjunction, and require an effort of analysis, aided by language, to separate them. This analysis may or may not be performed by this or that man, according to the circumstances in which he is placed. The forms of consciousness in general, and of its several modes,—personality, space, time, unity, plurality, totality,—may or may not be represented by the mind in their abstract character, as ideas or notions embodied in language; and the necessary truths based upon them may or may not be consciously discerned in the same character. A savage may never have contemplated the notions, *one*, *two*, *three*, *four*, &c., in the abstract: he may not know as an universal truth that two and two make four. But he knows the difference between a man and a tree, and he knows the difference between one man and many; and this knowledge contains the same ideas in the concrete. He embraces various sensible phenomena under the single notion of a man, though he has never asked himself the abstract question, How can the one be many, and the many one? Locke is, therefore, in one sense, right in denying the existence of innate ideas; for no idea can be formed independently of experience, and no idea need consciously be separated from the empirical accompaniments with which it is first manifested in con-

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gard the idea of power, as distinct from that of succession, as a pure delusion. And this is directly asserted by Hume, *Inquiry concerning Human Understanding*, sect. 7; *Human Nature*, part iii., sect. 14; by Brown, *Inquiry into Cause and Effect*, p. 18; and by James Mill, *Analysis of the Human Mind*, vol. ii., p. 256. Unfortunately, this theory does not inform as how, consistently with the laws of the imagination, such a delusion could have originated.

[1] It is necessary to specify *in a single succession;* as, in another sense, those phenomena may be called contingent, which do not uniformly, in various successions, follow from a given antecedent. But in this case the antecedent is not regarded as the cause of the consequent at all. But, in the case of any single occurrence, we are compelled to conceive that there is some antecedent or other on which it is dependent, and which being given, the occurrence could not but take place, *unless it is the result of an act of free will.* This conviction, with the exception, is the phenomenon to be explained.

[2] See *ante*, p.

[3] In this reduction of the apparent necessity of the causal judgment to an impotence caused by the absence of the data for thought, I must acknowledge my obligations to the corresponding portion of the theory of Sir W. Hamilton, *Discussions*, p. 609. This acknowledgment is the more necessary, inasmuch as, except in so far as regards the condition of relativity in time, I am compelled to dissent from the views of that eminent philosopher. His statement of the causal judgment, as an inability to think that the complement of existence has been either increased or diminished, is open to various objections. In the first place, I am not conscious of any such inability. I have no difficulty in conceiving that the amount of existence in the universe may at one time be represented by A, and at another by A+B. It is true that I cannot conceive nothing becoming something; for I cannot conceive nothing *per se;* but neither, on the other hand, can I conceive A, or any part of A, becoming B, while A remains at the same time undiminished. But the *result* is perfectly conceivable, though the *process* is not so, and cannot on any hypothesis become so. In the second place, whether we represent the new appearance as a *change* or as a *creation*, we are equally compelled to suppose a cause of its taking place. To say that B previously existed under the form of A, is not to explain the causal judgment; for we have still to ask why A became B. In the third place, the theory fails to account for the origin of the idea of *power*, which, whether rightly or wrongly, all men instinctively attribute to the supposed cause. To represent it as a delusion is not sufficient; unless it can be shown how, consistently with the limits of thought, such a delusion could have originated. I regret, however, that Mr Calderwood, with some of whose criticisms I concur, should have charged the above theory with pantheism. If ever there was a philosopher whose writings from first to last are utterly antagonistic to every form of pantheism, it is Sir William Hamilton. Pantheistic his theory certainly is not; for it represents the pantheistic hypothesis as the result of a mere impotence of thought, exalting its own inability to think into the measure of all possible existence.

[4] "Innate," says Lord Shaftesbury, "is a word he (Locke) poorly plays upon: the right word, though less used, is *connatural.* For what has birth, or progress of the fœtus out of the womb, to do in this case. The question is not about the *time* the ideas entered, but whether the constitution of man be such, that, being adult or grown up, at such or such a time, sooner or later (no matter when), the ideas of order, administration, and a God, will not infallibly, inevitably, necessarily grow up in him." The latter part of the criticism is not decisive; for Locke cites the adult savage to show that these ideas do not necessarily grow up. The true answer is, that experience itself is partly innate.

sciousness. But, precisely in the same sense, we may deny the existence of ideas of sensation; for sense alone could distinguish no two ideas from each other, without the co-operation of the understanding, which invests the materials furnished by sensation with certain universal and necessary forms. Instead of attempting to classify the actual phenomena of consciousness under one or the other head,—instead of saying that certain ideas are wholly empirical, and certain others wholly innate,—we should rather say that every phenomenon of consciousness contains an adventitious and a native element; and that, without the union of these two, no consciousness is possible. The criterion of universality and necessity marks the native or *à priori* element; but this criterion cannot be applied to the complex phenomena of any complete act of consciousness, but only to the element, when separated by an act of analysis, and embodied in that symbolical form which is not consciousness itself, but a substitute for it.

Cognate to this is another question of far greater importance:—What are the limits of thought? Is the mind capable of transcending the boundaries of all possible experience: and is such a power manifested by its possession of necessary truths? for necessity is not the result of experience. Experience tells us *what is*, but not *what must be*. Here, again, we must distinguish between the complete facts of consciousness and the several elements which are logically distinguishable from each other. If by *experience* is meant all that is presented in any mode of intuition, matter and form included; and if the question is understood to mean, Can we contemplate in thought any object which has never been presented as an element in any mode of intuition? the answer must undoubtedly be given in the negative. But experience in this sense contains a necessary as well as a contingent—a formal as well as a material element. Either of these may be contemplated in thought, apart from the other; and either may be contemplated in relations in which experience has never presented it. We have never seen a straight line, except as part of a surface; nor a surface, except as composed of some material, such as wood, or slate, or paper. But when thought, assisted by language, has enabled us to distinguish these concomitant phenomena from each other, we may reproduce in imagination the straight line as a modification of pure space, and contemplate its necessary relations in that character. Thought is so far dependent on experience, that where experience is impossible, thought is impossible likewise: it is so far independent of experience, that it can contemplate apart from each other the native form and the adventitious matter, which experience always presents in conjunction.

"The dominion of man," says Locke, "in this little world of his own understanding, is much-what the same as it is in the great world of visible things; wherein his power, however managed by art and skill, reaches no farther than to compound and divide the materials that are made to his hand; but can do nothing towards the making the least particle of new matter, or destroying one atom of what is already in being. The same inability will every one find in himself, who shall go about to fashion in his understanding any simple idea, not received in by his senses from external objects, or by reflection from the operations of his own mind about them."[1] The preceding remarks will show with what modifications this statement should be received. It is true, in so far as it asserts that nothing can be represented in thought which has not, separately or in conjunction with other phenomena, been presented in intuition; but it is incorrect, in so far as it overlooks the fact that intuition has a necessary element, derived from the constitution of the mind, as well as a contingent element, derived from the phenomena of sensation and reflection.

But whether we regard the objects of consciousness as presented in intuition, or as represented in thought; whether we look to the necessary or to the contingent elements of which they are composed; there is one limitation which the very conception of consciousness, as a relation between a subject and an object, necessarily implies, and to which in all its modes it must inevitably submit. Nothing can be presented in intuition, or represented in thought, except as *finite*. So long as the relation between subject and object exists in consciousness, so long each must limit the other. The subject is distinct from the object, and the object from the subject, and neither can be the universe. Nay, the object itself can only exist, as such, under the conditions of limitation and difference: it can be discerned only as one out of many; as implying the existence of other things besides itself; and hence, again, as a finite portion of the universe. The infinite cannot be an object of human consciousness at all; and it appears to be so only by mistaking the negation of consciousness for consciousness itself.[2] The infinite, like the inconceivable, is a term which expresses only the negation of human thought:—nay, the two terms are in fact synonymous, for conception is limitation. But the limits of possible thought are not the limits of possible existence. The infinite may, nay, must exist, though we cannot conceive it as existing; for the denial of its existence involves a contradiction, as well as the assertion of its conceivability. Hence we learn the important lesson, that the provinces of reason and faith are not coextensive; that it is a duty, enjoined by reason itself, to believe in that which we cannot comprehend.

From the above examination of necessary truths, it may be shown that no matter of fact can be a matter of demonstration in the highest sense of the term. For it is essential to demonstration that its object should be such as we can construct from within, out of the forms inherent in our own mental constitution; and it is essential to the existence of a fact, as such, that it should be presented to us from without. A fact, as such, must exist independently of my thinking about it: an object of demonstration, as such, exists only in and by the act of conceiving it. This consideration is sufficient to explain the failure of all attempts to demonstrate, *à priori*, the being and attributes of God,—a failure which should rather be a matter of rejoicing than of regret to the believer. If we can demonstrate the attributes of those objects only which we have constructed for ourselves, it follows that a demonstrated God is a creature of the human imagination. Such a demonstration is not, indeed, incompatible with the real existence of the Deity; as the domonstrations of geometry are not incompatible with the existence in nature of perfect geometrical bodies; but it adds not one tittle to the evidence of his existence; and it encumbers theology with arguments too pretentious not to provoke criticism, and too feeble to endure it. "Mischief," says Waterland, "is often done by pretending to strict and rigorous *demonstrations*, where we have no occasion for them, and where the subject is too sublime to go far in, with clear and distinct ideas. Such attempts serve only to make that become a matter of *question*, which before was *unquestionable*, while standing only on *reasonable* presumption or *moral* proof."[3] The triumph over a weak defence of a truth is too often regarded as a triumph over the truth itself; and we may therefore rejoice that theology, in the hands of its best exponents, has wisely abstained from resting its claims to belief on the evidence of rigid demonstration.

Lastly, we may observe that the distinction which various schools of philosophy, under various names, have attempted to establish, between the understanding and the reason, a separate faculties of thought, is, on the above principles, unnecessary, and therefore untenable. Whether, with the ancients, we distinguish between νοῦς and διάνοια, the intuitive and the discursive thought, the faculty of principles and the faculty of deduction from principles; or, with the moderns, especially in Germany, between understanding, as the faculty of generalization from the intuitions of consciousness, and reason, as the faculty which endeavours, intuitively or discursively, to apprehend the supreme conditions on which consciousness itself depends; we alike divide that which is one and indivisible, and attribute to the faculty of thought an operation which it never performs. The function of thought is in all cases the same, namely, to represent reflectively what is presented intuitively; and the existence of necessary as well as contingent principles in thought, is to be explained, not by a double operation of the thinking faculty, but by the existence of a corresponding distinction between necessary and contingent facts in intuition. The hypothesis of a faculty of reason distinct from understanding may indeed be necessary, as an assumption, to support the systems of those philosophers who aim at constructing a philosophy of the absolute and the infinite; for intuition, and therefore thought, as described in the preceding pages, takes cognisance only of the relative and the finite. But this assumption, consistently carried out, involves the annihilation of consciousness itself. But the mention of the absolute and the infinite reminds us that we are entering on the domain of the second portion of Metaphysics,—Ontology, or the Philosophy of Being.

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[1] *Essay*, b. ii., chap. ii., sect. 2.

[2] See on this point the admirable remarks of Sir W. Hamilton, *Discussions*, p. 12.

[3] *Dissertation on the Argument à* priori *for proving the Existence of a First Cause.* (*Works*, vol. iii., p. 371.)

II. ONTOLOGY; OR, THE PHILOSOPHY OF THE REALITIES OF CONSCIOUSNESS.

The term Ontology, or the Philosophy of Being, has become, in the estimation of no inconsiderable class of critics, a mere synonym for barren and useless logomachy. And it must be confessed, that the manner in which this field of inquiry has been frequently cultivated has gone far to explain, if not to justify, the contempt into which it has fallen. The philosophy which attempts to deduce a science of realities from the most abstract and general conception of existence must, from the necessity of the case, deal with words, and not with things. It has been already observed, in the preceding pages, that the human mind possesses no positive notion answering to the term *existence* or *being* in general; and it follows that there can be no law of the human reason which can indicate any necessary results involved in such a notion, and no fact of human experience which can give rise to a corresponding intuition. Every existence which we can perceive, is definite and particular, limited and related; and every existence of which we can think, is definite and particular, limited and related likewise. It must therefore needs be that a science which starts from the assumption of being in the abstract (which is not a conception, but an equivocal term, capable of relation to many distinct conceptions), and attempts, by pure deduction and division, to reason down to the concrete existences which alone are objects of positive thought, must end by delivering, not differences of things, but distinctions of words. And this must be admitted to be the case with the speculations of ontology in much of their ancient and mediæval, and in some stages also of their modern, development. The science was divorced from psychology; and was therefore destitute of facts, and compelled to supply their place by the signs of facts. Reversing the law of all reasoning, that of proceeding from the known to the unknown, it endeavoured to arrive at the truths which are immediately known in consciousness, by commencing with the unknown and unknowable beyond it. But, profitless as such attempts ever have been, and ever must be, there were not wanting circumstances in the history of philosophy, calculated to invest them with an apparent importance, and to engage acute and subtle intellects in the hopeless investigation. The science of mathematics was almost completed, in the essential features of its pure and abstract character, as the science of the relations of number and magnitude, at a time when its most important applications to the explanation of the phenomena of the material world were but dimly conceived, and not at all executed. With the triumphs of this science—the earliest, the clearest, the most rigorous in its reasonings, the most unassailable in its conclusions—before their eyes, the patriarchs of philosophy might be justified in believing that, in the law of intellectual progress, the abstract and rational must precede the concrete and empirical,—that the necessary relations of things in general must be determined prior to the investigation of the actual attributes of things in particular. But though the relation of mathematical to physical science presents, in some respects, an analogy to that between the rational and empirical philosophy of mind, the analogy unfortunately fails in the very feature that is most essential to scientific progress.

OF DOGMATIC OR DEMONSTRATIVE METAPHYSICS.

The demonstrations of geometry are due to the possession by that science of concrete as well as abstract axioms; of *à priori* intuitions of objects, as well as analyses of notions. Had the geometer been confined to such general and abstract principles as, that the whole is greater than its part, or that the sums of equal things are equal,—principles which indicate merely the logical analysis of thoughts, not the geometrical intuition of magnitudes;—had he been debarred, as some theorists have wished to debar him, from the use of the axiom of parallel lines, and the assumption that two straight lines cannot inclose a space, and other similar principles, many of which are implied, though not expressed, in all geometrical reasonings,[1]—his science would have remained to the end of time a science of words only. Yet it is upon the model of the merely logical principles that the majority of deductive metaphysicians have framed their fundamental assumptions.[2] Definitions of being in various senses of the term, and of the attributes coextensive with being; divisions and subdivisions, with explanations of each, and analyses of the contents of the several notions; have constituted, for the most part, the entire apparatus of ontological reasoning,—a reasoning which, being based entirely upon the logical conditions of thought, can attain to no other truth than that which is implied in the formal harmony of one thought with another, and the consequent consistent use of the language in which thoughts are expressed. And, accordingly, ontology, thus treated, obtained the name, more suited to its performances than to its pretensions, of a *lexicon of philosophical terms.*[1] It is manifest, however, that such a method involves, however little its professors may be aware of the fact, a virtual abandonment of the problem which ontology undertakes to solve. That problem, as has been before observed, is to determine the relation which exists between the necessities of thought and the constitution of things. But a science which starts with a definition of being in general, commences with one member only of this relation, the notion of *being as conceived by us.* To verify this conception, by showing that being as it is corresponds to being as we conceive and define it, it is necessary that the conception should be compared with something distinct from itself; and the data for this comparison cannot be supplied by a merely logical development of one notion from another.

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[1] It is with reference to these axioms that Kant proposes, as preliminary to all metaphysics, the question,—"How are synthetical judgments *à priori* possible?" For the general axioms are merely analytical judgments, in which the predicate contains nothing more than is already implied in the conception of the subject. The special axioms are the only ones in which an additional attribute is asserted of the subject; and, consequently, the only ones that can be considered as in any sense a statement of real relations.

[2] "Etenim Euclides demonstrationes suas in principia ontologica resolvit, quæ instar axiomatum absque probatione sumit; veluti quod totum sit majus qualibet sua parte, quod æqualia eidem tertio sint æqualia inter se." (Wolf, *Ontologia*, sect. 9.) In the same passage, these axioms are called "principia quæ mathesis pura ex ontologia mutuatur."

In point of fact, the speculations of demonstrative ontology accomplished far less than this. The analysis of a thought may be complete as a logical process, whether answering to reality or not, provided that its fundamental assumption represents at starting a positive and intelligible conception. But the fundamental assumption of ontology, that of *ens*, or *being in general*, represents nothing of the kind. What is being in general, apart from the special modes of being which are manifested in consciousness? When, in the crucible of abstraction, self and not-self, the factors of consciousness, and every special modification of either, have evaporated, what remains as the residuum? Absolute zero; a mere word with no thought answering to it; a being which is neither my being nor that of anything else, and which is therefore removed from all the conditions under which being is, or can be, made known to us. I have no conception of being in general which is not some being in particular; and to assume that the various modes of being which consciousness reveals to us are but subordinate species of one and the same genus, is to assume a fact which consciousness does not testify, and which, if it can be proved at all, must be the conclusion, and not the premise, of the science that deals with it. Deductive ontology, by assuming being as its starting-point, necessarily abandons thought to juggle with words.[2]

OF THE SUBDIVISIONS OF DOGMATIC METAPHYSICS.

A metaphysic of being in general, even if successful in its aim, can only be regarded as a preparation for a more special philosophy. Even if it could solve its own problem, it would answer none of the important questions which connect metaphysical inquiries with the interests and destinies of man; it would satisfy none of the yearnings which compel men to undertake the study of them. The ideas of God, of freedom, and of immortality, are too special to be elicited by the processes of general ontology, except in the form of pantheism, which disposes of them by annihilating them altogether. The idea of God becomes merged in that of the sum total of existence; that of freedom is destroyed by representing this quasi-deity as the sole real agent; that of immortality is exchanged for an absorption of the phenomenal self into the real universe. To preserve the heirlooms of human reason intact, it was necessary for philosophy to descend from the region of pure abstraction into one in which the conception of being could assume a more definite form. And here, at least, the investigations of the metaphysician had the advantage of starting from the testimony of consciousness. Every act of consciousness is given to us as a relation between *self* and *not-self.* These two elements, as mutually related, are necessarily viewed as modifying and limiting each other. But the consciousness of the relative and the limited suggests, by inevitable association, the notion of the absolute and the unlimited as its contrast. Hence arise the three fundamental ideas which underlie the whole fabric of ontological speculation,—conditioned existence, manifested in the two relative and finite forms of the *ego* and the *non-ego*; and unconditioned existence, implied in the suggestion of the absolute and the infinite. The investigation of these ideas has given rise to three branches of metaphysical philosophy,—rational psychology, rational cosmology, and rational theology:—the *ego* being identified with the human soul, regarded as a substance distinct from its phenomenal modifications;[3] the *non-ego* with the reality which manifests itself in the sensible world; and the absolute or unconditioned with the Deity.[4] But, in the prosecution of these inquiries, metaphysicians committed the same error which has been already noticed as vitiating the theories of being in general. They deserted the facts of consciousness, to take refuge in abstractions, of which we are not, and cannot be, conscious. Let it be granted that every phenomenon implies a corresponding reality; that the phenomena of the *ego* indicate the existence of the human soul; and the phenomena of the *non-ego*, that of a substantial universe; and the relation between the two, that of a being who is beyond relation;—still, in no fact of consciousness is the reality given apart from the phenomena which are related to it. The notions of an abstract self, modified in no particular manner; of an abstract world, isolated from the special phenomena of sense; and of an abstract Deity, apart from those finite attributes by which he is manifested in relation to the finite consciousness of mankind, can be given in no phase of consciousness; for if they were, the relation and succession which constitute consciousness would be annihilated. Whether these three metaphysical ideas all stand on the same footing within the domain of consciousness itself, is a question which we shall have to ask hereafter; but, assuming for the moment that they do, and assuming that in each there is a legitimate passage from the phenomena presented in consciousness to the ultimate realities beyond, it is clearly begging the whole question, and anticipating the inquiry which philosophy has not yet commenced, to start with the abstract notions of such realities, as if the problem had been already solved, and the passage found. Hence, like ontology in general, the three branches of ontology, if deductively treated, will deal with words and not with things. Unable to verify their fundamental assumptions by an appeal to the facts of consciousness,—unable even to determine whether those assumptions represent thought or the negation of thought,—they can but torture words under the name of analysing notions, and arrive at conclusions which indicate no more than a consistent use of language. Thought itself, in its bare and unmixed form, cannot be handled in any mental process. It must be contemplated either in the words which represent it, or in the things which it represents, or in the union of the two; and the whole difference between reasoning and logomachy depends upon a single criterion:—Can the relations of language, which our process exhibits as representing thought, be verified by an appeal to the facts of consciousness, of which thought itself is the representative? Such an appeal is manifestly impossible to those who commence their inquiries by assuming an abstraction of which consciousness does not and cannot take cognisance.

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[1] Wolf, *Ontologia*, sect. 25.

[2] The following summaries, extracted from the works of two eminent metaphysicians of the seventeenth and eighteenth centuries, may enable the reader to form some notion of the treatment of ontology, in systems prior to the criticism of Kant. The contents of Burgersdyk's *Institutiones Metaphysicæ* are enumerated as follows:—"De natura metaphysicæ—De communi entis notione—De eo quod est medium inter ens et nihil in genere—De privatione et denominatione externa—De ente rationis—De relatione—De modis entium—De principiis incomplexis sive essentia et existentia—De principiis metaphysicæ complexis—De entis affectionibus in genere—De unitate et multitudine in genere—De unitate numerica et formali, de que principio individuationis—De unitate universali—De speciebus et gradibus unitatis—De diversitate sive distinctione et convenientia—De oppositione—De ordine—De veritate et falsitate—De adjunctis veritatis—De bono et malo—De localitate, temporalitate et duratione—De toto et parte—De causa et causato in genere—De causa materiali—De causa formali—De causa efficiente—De fine—De subjecto et adjuncto—De eo quod est necessarium, impossible, contingens et possibile—De potentia et actu—De perfecto et imperfecto, sive perfectibili et perfectione." The contents of Wolf's *Ontologia* are of a similar character:—DE NOTIONE ENTIS IN GENERE ET PROPRIETATIBUS QUÆ INDE CONSEQUUNTUR—*De principiis philosophiæ primæ*—De principio contradictionis—De principio rationis sufficientis—*De essentia et existentia entis, agnatisque nonnullis notionibus*—De possibili et impossibili—De determinato et indeterminato—De notione entis—*De generalibus entis affectionibus*—De identitate et similitudine—De ente singulari et universali—De necessario et contingente—De qualitate et agnatis notionibus—De ordine, veritate, et perfectione—DE SPECIEBUS ENTIUM ET EORUM AD SE INVICEM RESPECTU—*De ente composito*—De essentia entis compositi—De extensione, continuitate, spatio et tempore—De qualitatibus et magnitudine entis compositi—De motu—*De ente simplici*—De differentia entis simplicis et compositi—De modificatione rerum præsertim simplicium—De finito et infinito—*De respectu entium ad se invicem*—De dependentia rerum earumque relatione—De causis—De signo.

[3] The character of rational psychology, as distinguished from empirical, is thus stated by Wolf,—"Definio *psychologiam empiricam* quod sit scientia stabiliendi principia per experientiam, unde ratio redditur eorum quæ in anima humana fiunt . . . . In psychologia rationali ex unico animæ humanæ conceptu derivamus à priori omnia quæ eidem competere a posteriori observantur et ex quibusdam observatis deducuntur." (*Philosophia Rationalis, Disc. Prælim.*, sect. 111, 112.) Compare Herbart, *Allgemeine Metaphysik*, sect. 29.

[4] These three objects of metaphysical inquiry,—God, the world, the soul,—answer to Kant's three ideas of pure reason; but he arrives at them in a different way; namely, by regarding them as all alike intimations of the unconditioned, suggested by the three kinds of logical syllogism;—a derivation fanciful and extravagant, and which nothing but the profound genius of its author could have rescued from utter absurdity.

Thus, to illustrate our remarks by special instances, the aim of rational psychology is to frame definitions exhibiting the essential nature of the soul and its properties, as realities conceived by the intellect, underlying and implied by the phenomena presented in consciousness; and to prove by a demonstrative process that the notions thus defined necessarily flow one from another. Psychology is thus raised from a science of observation to one of demonstration; and its objects are transformed from phenomena presented in experience to realities contemplated by the intellect. The soul, by virtue of its essential nature as a simple substance, is shown to possess, of necessity, certain attributes as rationally conceived and defined—such as sense, imagination, intelligence, will, spirituality, indestructibility, and so forth; and the same conclusions are even demonstrated of other spiritual natures which partake of the generic attributes of the human soul.[1] The weakness of the whole process is, that it tacitly postulates as its starting-point a principle which is neither evident in itself, nor such as can be made evident by any process of thought. It assumes, that is to say, a transcendental definition of the real nature of the soul, beyond and above those facts and relations which are manifested in consciousness. But how is the truth of such a definition to be guaranteed? Of the soul as a simple substance, apart from its particular modifications, consciousness tells us nothing. Its permanent existence is known only in conjunction with and by means of its successive modifications. How, then, is this abstract conception of the nature of the soul to be verified? It cannot be self-evident; for self-evidence is nothing more than the instantaneous assent of consciousness; and the assumption in question cannot be submitted to the judgment of consciousness at all. It cannot be demonstrable; for it could only be demonstrated by the assumption of a higher notion of the same kind, concerning which the same question would then have to be raised. It cannot be generalized from experience; for experience deals with the facts of consciousness only, and tells us not of what *must be*, but only of what *is* or *seems to be.* Unable to verify his fundamental definition by any reference to the reality which it is supposed to represent, the metaphysician is compelled to confine himself to the relations of the language by which it is represented.

The case is still stronger as regards the other two branches of deductive metaphysics. Cosmology, as exhibited by Wolf, professes to deduce, from ontological principles, a demonstration of the nature of the world and the manner in which it is produced from simple substances.[2] The world, according to this method, is represented as an absolute whole, or entire system of causes and effects, which cannot be conceived as itself a part of any greater whole;[3] and the office of cosmology is to deduce, from the abstract principles of being in general, the necessary relations which the world, as a compound being, must exhibit. It is thus based, not on an examination of the mundane phenomena as they actually exist in the present system of nature, but on the general conception of the world, as a possible system, under which the actual system is included, as an individual under a species.[4] Cosmology, as thus exhibited, can contain nothing more than an analysis of general notions, and can lead to no conclusions but such as the philosopher has himself virtually assumed in his premises. The abstract notion of the world contains implicitly whatever attributes we choose to assume as its constituents; and the metaphysical or logical analysis of that notion can contain no more. For the world, as a possible system of realities, and not as an actual system of phenomena, is not an object of intuition, pure or empirical; and, without intuition, it is impossible to connect the concepts of the understanding with a single attribute, beyond those which they contain in their original comprehension.[5]

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[1] The following table of the contents of Wolf's *Psychologia Rationalis* will exhibit a brief summary of this method,—"*De anima in genere et facultate cognoscendi in specie*—De natura et essentia animæ—De facultate sentiendi, sive sensu—De imaginatione et memoria—De attentione et intellectu—*De facultate appetendi*—De appetitu sensitivo et aversatione sensitiva atque affectibus—De appetitu et aversatione rationali, seu de voluntate et noluntate—*De commercio inter mentem et corpus*—De systematis explicandi commercium inter mentem et corpus in genere—De systemate influxus physici—De systemate causarum occasionalium—De harmonia præstabilita—*De variis animœ attributis, spiritu in genere, et animabus brutorum*—De spiritu in genere et spiritualitate animæ in specie—De animæ ortu, unione cum corpore, et immortalitate—De animabus brutorum." Compare Kant, *Kr. der r. v. Transc Dial*, B. ii., H. 1. Hegel, *Encykl.* sect. 34.

[2] Wolf, *Cosmologia Generalis*, sects. 2, 7. The following are the questions discussed by Wolf in this work, as constituting a metaphysical theory of the material world—*De notione mundi seu universi*—De rerum nexu et quomodo inde universum resultet—De essentia mundi et ejus attributis—*De notione corporum ex quibus mundus componitur*—De essentia et natura corporum—De elementis corporum—De ortu corporum ex elementis—De legibus motus—*De natura universa et perfectione mundi*—De natura universa in genere, itemque naturali et supernaturali—De perfectione mundi—De ordine mundi atque naturæ.

[3] Kant, *Leçons de Metaphysique traduites par Tissot*, p. 144.

[4] Wolf, *Cosmologia*, sect. 49.

[5] "Cosmology," says Hegel (*Encyklopædie*, sect. 35), "treated of questions concerning the contingency or necessity of the world, its eternity or limitation in space and time, and the formal law of its changes; together with those concerning human freedom, and the origin of evil. It contemplated its object, however, not as a concrete whole, but only according to abstract definitions. Thus, for example, it discussed such questions as, whether the world is subject to chance or necessity; whether it is eternal or created." A portion of the questions here mentioned were sometimes transferred to other branches of metaphysics; but the method in all cases was the same, and the results equally barren.

This criticism is still more applicable to the system of rational theology. In this science, we are supposed to start from a nominal definition of the Deity, as the most perfect being, containing in his nature the sum of all possible realities in an absolutely perfect degree.[1] But here again the question arises,—How do we know that our conception at all corresponds to the nature of the being whom it professes to represent? The object, which the conception represents, is either given in some fact of consciousness, or it is not. If it is not given, I cannot compare the conception with its object; for comparison is itself an act of consciousness, and cannot be applied to anything of which I am not conscious. If it is given, it must be given, like all other facts of consciousness, in the form of an object related to myself. By what right, again, do I venture to transcend that relation, and assume that what is given in relation to me is identical with that which exists out of all relation. We are not, be it remembered, discussing the sufficiency of the religious consciousness for the spiritual wants of man: we are only examining the claim of the metaphysician to found thereon a system of absolute and necessary truths. Such a system claims, in its very conception, a right to transcend consciousness. The form of consciousness is *myself*, and the facts of consciousness postulate my existence as their condition. By what warrant am I justified in reasoning from the relative to the absolute,—in identifying that which depends on me with that on which I depend. A conception of the Deity, in his absolute existence, appears to involve a self-contradiction; for conception itself is a limitation, and a conception of the absolute Deity is a limitation of the illimitable.

OF THE CRITICAL PHILOSOPHY OF KANT.

The above method of dogmatic metaphysics, of which the most complete specimen is furnished by the writings of the celebrated Leibnitzian philosopher, Wolf, received its death-blow from the criticism of Kant. The fundamental position of the Wolfian dogmatism consisted in the assumption that the realities of the intelligible world constitute a system of immutable truths, which furnish the reason and the explanation of the phenomena of the world of sense. The counter-theory of Kant consisted in showing that the conceptions of the understanding and the ideas of the reason are equally phenomenal and relative with the intuitions of sense. The whole field of consciousness, reflective as well as sensitive, he argued, is the product of an objective and a subjective element, and can in no case be regarded as the exact representation of an extra-mental reality. We can perceive only as the laws of our intuitive consciousness, exhibited in the forms of space and time, permit: we can think only as the laws of our reflective consciousness, manifested in the categories of the understanding, permit. The product, in both cases alike, is not a *thing in itself*, but a *phenomenon*, or thing such as the laws of our mental constitution determine it to appear to us. The object, in one mode of consciousness as much as in another, is coloured by the medium through which it passes to reach the mind; and, in bringing the phenomena of sense before the tribunal of intellectual conceptions, we are not comparing the phenomenal with the real, the representation with the thing represented; we are only comparing one class of phenomena with another, and judging the representations of the human senses by the representations of the human understanding. Even the ideas of the reason, which correspond to the three great objects of metaphysical inquiry,—God, the world, and the human soul,—are not representations of objects actually discerned in their own nature, but regulative principles of thought, fallaciously invested with an objective existence. A necessity of thought manifestly indicates a law under which we must think; but it does not therefore guarantee the existence of a corresponding reality out of thought. The true *thing in itself*, the *being*, as distinguished from the *phenomenon*, is not the object such as we are compelled to conceive it, but the object out of all relation to our faculties; and, as such, it is manifestly unknown and unknowable. To perceive a thing in itself would be to perceive it neither in space nor in time; for these are forms furnished by the constitution of our perceptive faculties, and form an element of the phenomenal object of intuition only. To think of a thing in itself would be to think of it neither as one, nor as many, nor under any other category;[2] for these, again, depend upon the constitution of our understanding, and form an element of the phenomenal object of thought. The phenomenal is the product of the inherent laws of our own mental constitution, and, as such, is the sum and the limit of all the knowledge to which we can attain.

The logical result of Kant's speculative philosophy (of his practical philosophy we can say nothing at present), was to prove that real being cannot be an object of human thought; and, consequently, that a system of ontology, in the highest sense of that term, is unattainable by human reasoning. But, partly in consequence of the inconsistencies of Kant himself, and partly because of the sweeping scepticism to which his method at least appeared to lead, it was almost inevitable that his successors should attempt to reconstruct on a surer basis the dogmatic metaphysics which his criticism had overthrown. The Kantian philosophy had confined itself too much to negative results: it had demonstrated the inconclusiveness of the earlier systems of metaphysics: it had exhibited in the clearest light those apparent self-contradictions of the human reason which make metaphysics, in some form or other, an intellectual necessity to man; but it had not attempted to solve the contradictions it exhibited: it had neither pointed out the way to a surer metaphysical system, nor placed the reason in a position to dispense with metaphysics altogether. Kant had only succeeded in showing that the household of human consciousness was divided against itself: he had neither been able to merge the contradiction in a higher principle of unity, nor to show that contradiction itself is an evidence of truth and reality. The want which a philosophy of the real attempts to satisfy still remained; and to meet that want it was necessary to reconstruct metaphysics by another method. Kant had proved that the real, in its highest sense, could not be an object of consciousness: his successors accepted the conclusion, and consistently attempted to construct a philosophy of the real which should be above consciousness. Kant had proved it to be impossible to bring the object in itself within the grasp of the subject: there remained the yet wilder attempt to expand the subject to the immensity of the object,—an attempt which necessarily ended in the identification and consequent annihilation of both.

OF THE SYSTEMS OF FICHTE, SCHELLING, AND HEGEL.

The philosophy of Fichte furnished the transition from a destructive criticism to a new form of constructive dogmatism. The primitive fact of consciousness is that of a relation between the *ego* and the *non-ego*, between *myself*, the conscious subject, and an object of which I am conscious. But, thus manifested, self and not-self are correlative terms, existing for each other only under the conditions of human consciousness; that is to say, as *phenomena*, in Kant's sense of the term. To attain to a philosophy of the real, it was necessary to merge this primitive relation between the subject and object of consciousness in a higher relation between the entire world of phenomena revealed by consciousness, and the ultimate reality beyond it. And this was partly accomplished by the theory of Fichte. Consciousness, in this system, is manifested solely as a modification of the *ego;* and the *ego* itself must be supposed to exist prior to, and independently of, any special modification of its existence. Hence the first postulate of philosophy is that of the existence of an absolute *ego* or unconscious subject, susceptible potentially of all modes of consciousness, but actually modified by none. The first formula of Fichte's system, "$A = A$," or the *ego* posits itself,[1] may thus be interpreted to mean, "the fact of a necessary thought implies the existence, not only of an actual thinker, but of a real subject, capable of becoming a thinker." But this real subject, though existing independently of consciousness, becomes aware of its own existence only in and by consciousness. And consciousness, as a particular phenomenon, depends upon something by which the impulse is given to the subject, whereby it determines itself to become conscious. Hence the *ego*, in becoming conscious of its own existence, supposes at the same time, though it is not conscious of, the existence of a *non-ego.* And this is expressed by the second formula "$-A \neq A$; or, the *ego* implies a *non-ego.*" But this implied *non-ego* is merely supposed by an act of thought, in order to account for the fact of the *ego* becoming conscious of itself. Hence arises the third formula of Fichte's system, "The *ego* and the *non-ego* are both posited by the *ego* itself,"—in other words, the relative and conscious *ego*, and its counterpart, the *non-ego* implied by consciousness, both owe their existence to the fact that the absolute *ego* becomes conscious of itself. Hence these are posited in and by the absolute *ego.*

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[1] The following are the matters treated of in the second or *à priori* portion of Wolf's *Theologia Naturalis*:—"De notione entis perfectisimi et ejus existentia—De intellectu Dei—De voluntate Dei—De creatione, providentia, et potentia Dei—De atheismo—De fatalismo, deismo, et naturalismo—De anthropomorphismo, materialismo, et idealismo—De paganismo, manichæismo, spinozismo, et epicuræismo."

[2] For a list of the Kantian categories, see *ante*, p. 586.

The absolute *ego* is thus the one primitive existence, and, as such, must be absolutely free. Hence, in becoming conscious, the *ego*, by a free act, creates the whole contents of its consciousness—the modified *ego* and the *non-ego* together. The *non-ego* of Fichte thus assumes the position which in the Kantian philosophy was occupied by the *thing in itself*, being not the object of consciousness, but the supposed reality beyond; and this supposed reality is itself shown to possess only a secondary and derivative existence, being postulated to account for the fact of consciousness; which fact itself is the result of the self-determination of the absolute *ego.*

The error of this system (an error shared by most of the subsequent developments of German metaphysics) is, that it attempts to explain and account for the primitive dualism of consciousness, instead of accepting this fact as the principle from which the explanations of philosophy must take their start. Hence we have the contradictory ideas of an *ego* absolutely free, and yet compelled to posit the existence of a *non-ego.* The *ego*, we are told, strives to realize its own freedom. How came that freedom ever to be impaired or to need realization? Does anything ever freely operate to its own deterioration? Or rather, we may ask, does not freedom itself imply consciousness? Is it not a self-contradiction to suppose a free agent unconscious of its own freedom? The philosophy which starts from the single being of God is presumptuous enough, and deals sufficiently with the incomprehensible. But Fichte's system, in making *the ego* the first principle of all things, leaves no room for the distinct existence of a Deity; and hence Fichte is compelled to confess that he knows no other God than the moral order of things.[2] In this unsatisfactory position, the absolute *ego* is compelled to give way to a higher idea; and thus Fichte's later philosophy, while retaining its original terminology, virtually passes over to a new position, in which he had been already anticipated by Schelling.

The rival theories of Schelling and Hegel present the most perfect specimens, from two opposite points of view, of a system of metaphysics constructed, not merely independently of, but in direct opposition to, the laws of consciousness. The *ego* and *non-ego* of Fichte, in their original form, were entities beyond consciousness, but not necessarily antagonistic to it:—on the contrary, they were rather represented as harmonizing with and explaining consciousness itself. But as thus implied by, and yet not given in, consciousness, they necessarily remained unknown and unknowable. Consciousness might, perhaps, justify the inference *that* they are; but it could not possibly inform us *what* they are. The entities of Fichte were thus, though arrived at by a different process, virtually the same as those of the older metaphysicians,—the unknown subjects or causes of sensible or intellectual phenomena. To make the real an object of science, it was necessary that it should be directly given or revealed to intelligence:—there must be an absolute knowing to answer to the absolute being. Philosophy must postulate, not merely an object of knowledge beyond consciousness, but a manner of knowledge above it; and this was attempted in two ways,—by Schelling, from the side of the presentative faculties; and by Hegel, from that of the representative. The former based his philosophy on the fiction of an intellectual intuition emancipated from the conditions of space and time; the latter, on that of a logical reason emancipated from the laws of thought.

In the philosophy of Schelling, the *ego* is stripped of even the small remnant of personality which it retained in the original scheme of Fichte. That which in Fichte's system appears as an abstract *self*, modified in no particular manner, but susceptible of modification in any, becomes, from Schelling's point of view, abstract intelligence in general, having no personality, but capable of becoming personal. In Fichte's system, the absolute *ego* creates the several modes and objects of its own consciousness. In Schelling's, the absolute intelligence, by a free act, creates its own personality with its modes on the one side, and the material world, or system of nature on the other.[3] Thus the object, which in Fichte's system is posited by the subject, becomes in Schelling's identified with it; subject and object being merged in the absolute, which in its own nature is the indifference of the two, and which creates the distinction by becoming conscious of itself.[4] The system is thus at the same time realism and idealism: the world of things and the world of thought are but two opposite aspects of one and the same being, manifesting itself without or with consciousness.[5] The human reason is identical with the divine; and philosophy is the reproduction of creation, or rather is creation itself; for the philosophy of the absolute is above the condition of time: it is not an imitation or repetition of the divine thought, but the divine thought itself developed into consciousness.

It is obvious to ask how such a system, admitting it to be possible or even true, can be known to be possible or true. Can the individual man, supposing him to be a phenomenon and not a reality, become conscious of his own nonentity? The first testimony of consciousness is to the existence of the conscious subject: the idea of reality and existence arises in and by that testimony. Can I then, existing in consciousness, be at the same time conscious that I do not exist? Can I be conscious and not conscious, substance and accident, reality and phenomenon, personally existing and merged in the absolute, at one and the same instant, in one and the same act? This Schelling's theory virtually declares to be possible, and the means by which it is accomplished is intellectual intuition. This intuition is the instrument and the method of philosophy: it is the process by which the absolute becomes conscious of itself, by which the philosopher becomes conscious of his identity with the absolute.[1] It is an act out of time, and by which time is constituted; an act which is distinct from and above ordinary consciousness, which cannot be described in language or apprehended in conception, whose results cannot be communicated to ordinary consciousness, and, of course, cannot be verified by it.[2]

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[1] *Grundlage der gesammten Wissenschaftslehre*, sect. 1.

[2] *Ueber den Grund unseres Glaubens an eine Göttliche Weltregierung. Werke*, vol. v., p. 186.

[3] *Ideen zu einer Philosophie der Natur*, p. 9, sqq. (2d edition). *Bruno*, p. 57, sqq. (2d edition).

[4] *Ideen*, p. 67, sqq. *System des transcendentalen Idealismus*, p. 480.

[5] *Ideen*, p. 64. *System des tr. Idealismus*, p. 17.

Let us grant for an instant such an abnormal state to be possible. Let us grant even that the state being above conception it is no argument against it that its conception is self-contradictory and annihilates itself. What even then would be proved, save that one portion of our knowledge is at variance with another, and that there is no arbiter to decide between them? *Cogito, ergo sum;* the act of knowledge is an act of personal existence:—this is the testimony of the normal consciousness. *Cogito, ergo non sum;* the act of knowledge is an act in which personal existence disappears in the absolute:—this is the testimony of the abnormal intuition. Neither of these can judge the other; for neither testimony can be translated into the language or represented in the thought of the other. It is mere idle boasting for the would-be philosopher to assert the superiority of his instrument over that employed by the rest of mankind; for superiority implies comparison, and comparison is an act of relation, and relation annihilates the absolute as such.[3] The controversy must remain undecided until a third faculty shall be discovered, which, being, in one and the same act, normal and abnormal, conscious and not conscious, existent and non-existent, may embody in one process the results of intellectual intuition and ordinary consciousness, and examine them on common principles before a common tribunal.

Something like this union of all contradictories is proclaimed in the logical idea of Hegel, the supreme principle of all truth and of all reality.[4] The method of Hegel commenced by attempting to justify the assumption of Schelling, and ended by superseding it. While admitting, as substantially true, the fundamental principle of Schelling's philosophy, the unity of subject and object in the absolute, Hegel protests decidedly against the method by which, according to Schelling's theory, this principle is apprehended. The intellectual intuition, which is demanded as the condition of all philosophy, is a faculty which any individual may or may not possess. The philosophy of Schelling thus appears to demand, as its condition, a special artistic talent or genius, an accidental gift of good luck. But philosophy must, from its nature, be capable of becoming common to all men; for it is based upon thought, and thought is the characteristic of man as man.[5] But the logical process which Hegel announces as common to all men is at least as far removed from the conditions of normal intelligence as the extraordinary endowment demanded by Schelling. The postulate upon which the entire system rests—the identity of thought and being—is constantly asserted, but never proved; and this assumed identity necessitates a conception of thought not only distinct from, but at variance with, the evidence of consciousness. Thought in consciousness is manifested in the form of successive modifications of the personal self, relative, determinate, special states of my individual existence. Thought in the system of Hegel is represented as an impersonal, absolute, indeterminate, universal, unconscious substance, determining itself in opposed and yet identical modifications, becoming all things, constituting the essence of all things, and attaining to consciousness only in man. Consciousness is thus the accident, not the essence, of thought; and the unconscious process of the idea in nature is regarded as fundamentally one with the conscious development of human intelligence. Hegel's famous theory of the identity of contradictions derives its whole plausibility from a twofold confusion,—of thought with being, and of identity with coexistence. In consciousness, two identical thoughts are undistinguishable from each other; and as consciousness is only possible as a cognition of differences, it follows that a system of identical determinations of consciousness is tantamount to the annihilation of all consciousness. The possibility of consciousness, therefore, implies the coexistence of opposites; but, for the very reason that there is coexistence, there is not identity. Any special modification of consciousness is discerned to be that which it is by being distinguished from that which it is not; and in this manner consciousness is only possible on the condition of a relation, not merely between subject and object, but between a plurality of objects opposed to each other. But, in order that these opposite objects should be regarded as identical, or rather as constituent elements of one and the same reality, it is necessary that the *notion* or *thing in itself* should be represented, not as a single object of consciousness, but as an unperceived substratum which underlies the relation between the two opposed objects, and out of which they mutually spring as distinct sides of one and the same reality. Being is thus no longer identical with thought;—or rather the term *thought* is used in an equivocal sense, to denote consciousness and unconsciousness at the same time. But it is nowhere explained how this abstract thought can exist independently of a thinking mind; nor how, supposing it to exist, and supposing the philosopher to become conscious of its existence, his consciousness is thereby identified with the object of which he is conscious.

The method of Hegel is sometimes described as an attempt to *re-think the great thought of creation;*[6] the philosopher being supposed to place himself at the point at which the Divine mind developed itself into finite existences, and to repeat that development in the process of his own system. This supposition is sufficiently presumptuous; but, as usually understood, it by no means expresses the full pretensions of Hegel's theory. Creation, in the Hegelian point of view, does not imply a creator, nor thought a thinker. Instead of commencing with God, as the beginning of all existence, this philosophy commences with zero. The *notion*, whose development constitutes the process alike of existence and of thought, is pure being, which is identical with pure nothing.[1] The union of being and nothing constitutes becoming;[2] and from becoming proceeds all determinate existence. The Hegelian process may thus be described as a creation of the Deity no less than of the world; for it recognises the existence of no Deity distinct from the world. But the philosopher, though aspiring to construct the universe, is virtually compelled to assume a prior universe as his foundation. Though he will not postulate a mover, he is compelled to postulate motion. The pure being, which is also pure nothing, has a power of self-development.[3] How this process takes place; or how pure nonentity can contain a principle of self-development; or how, if being and nothing are absolutely one and the same, they can at the same time be two elements united together; or how the union of the identical with the identical can form a compound distinct from its factor or factors,—these points Hegel has omitted to explain.

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[1] *System des tr. Idealismus*, p. 50, sqq.

[2] *Ibid.*, pp. 59, 471.

[3] The acute and decisive criticism of Schelling's theory by Sir W. Hamilton, is too valuable to be omitted in this place. "We cannot at the same moment be in the intellectual intuition and in common consciousness; we must therefore be able to connect them by an act of memory—of recollection. But how can there be a *remembrance* of the absolute and its intuition? As out of time, and space, and relation, and difference, it is admitted that the absolute cannot be construed to the understanding. But as remembrance is only possible under the conditions of the understanding, it is consequently impossible to remember anything anterior to the moment when we awaken into consciousness; and the *clairvoyance* of the absolute, even granting its reality, is thus, after the crisis, as if it had never been." (*Discussions*, p. 23.)

[4] In the words of Hegel himself, "Die Idee kann als Subjekt-Objekt, als die Einheit des Ideellen und Reellen, des Endlichen und Unendlichen, der Seele und des Leibs, als die Möglichkeit, die ihre Wirklichkeit an ihr selbst hat, as das, dessen Natur nur als existirend begriffen werden kann u.s.f. gefasst werden, weil in ihr alle Verhältnisse des Verstandes, aber in ihrer unendlickken Rückkehr und Identität in sich enthalten sind." (*Encyklopädie*, sect. 214.) In the words of his disciple and expositor, Michelet:—"Die Idee ist als Werden, die Einheit von Sein und Nichts, als Unendliches, die Einheit des Etwas und seines Andern; Wesen und Erscheinung, Form und Materie, Inneres und Aeusseres, Möglichkeit und Wirklichkeit, Allgemeines und Besonderes, u.s.f. sind ebenso darin zur Identität gekommen" (*Geschichte der letzten Systeme der Philosophie*, vol. ii., p. 745.

[5] *Geschichte der Philosophie. Werke*, vol. xv., p. 592.

[6] "Den grossen Gedanken der Schöpfung noch einmal zu denken." Such, according to Hegel's editor, Michelet, is the true business of

There is a germ of truth in Hegel's opening paradox, "pure being is pure nothing," if it be understood as applied, where alone we have any data for applying it, to the necessary limitations of human thought. The conceptions of man are limited to the finite and determinate: we can conceive existence only under the conditions of relation and difference, as this particular kind of existence, distinguished from others. The conception of being in general which is no being in particular, is thus, to human intelligence, no conception at all; it indicates only the absence of any definite object of thought, and consequently of any power of thinking. But to convert this negation of the relative into an affirmation of the absolute, is to go beyond the ancient sophist, to make man's ignorance, instead of his knowledge, the measure of all things, and thus to dogmatize on no other grounds than the absence of all materials for dogmatism. And even this apotheosis of human impotence does not guarantee the fundamental assumption of the system; for if being is the same as non-being, and if being and thought are one, thought is also identical with the negation of thought; and the absolute thinking, which is absolute existence, is, by the same argument, no thinking at all.

OF THE SYSTEM OF HERBART.

The idealist systems of Fichte, Schelling, and Hegel, while differing considerably in their details, were characterized by one common principle. They all sought to escape from the phenomenal and relative character of the products of consciousness, by placing real being in an unity above consciousness. In antagonism to these, another offshoot of the Kantian criticism, the realism of Herbart, sought to attain the same end by means of a plurality below consciousness. The one attempted to generalize beyond the limits of thought; the other, to individualize beyond the limits of sense. According to Herbart, all the original notions which we form of the objects presented to us by experience, whether as regards external or internal phenomena, are, upon examination, found to involve contradictions, and thus to condemn themselves as inconceivable. The office of metaphysics is so to modify these notions as to remove the contradictions, and thus to reconcile the testimony of experience with the requirements of thought.[4] To attain this end, Herbart has recourse to a modified form of Leibnitz's theory of monads.[5] The phenomena of experience are regarded as dependent on the mutual relations of a number of real or absolute beings, simple, unextended in space, and subject to no succession in time, and thus without parts and without change. We are thus, he thinks, enabled to avoid the fundamental contradiction of experience, with which all philosophy has to struggle,—the antagonism between the one and the many; we escape from the paradox of maintaining that the same *thing* can consist simultaneously of various elements, or exist successively in various states. Every real being is simple in itself, though different one from another: the world of sensible experience is but an aggregate of phenomena, resulting from the mutual attraction and repulsion of insensible units; and the principle which pervades the whole is the effort of each unit for self-conservation.

Among many merits of detail, it is impossible to overlook the weakness of Herbart's fundamental assumption. His system, by deriving the known world of relations from an unknown world of absolute beings, postulates ignorance as its starting-point, and makes philosophy dependent on an assumption whose only guarantee is, that we have no means of verifying it. The existence of the supposed world of realities is unknown; for it confessedly lies beyond the limits of experience; and mere thought does not prove the reality of its object. Its relation to the world of phenomena is unknown; for the knowledge of a relation implies the knowledge of both correlatives. Its existence is assumed in order to solve certain supposed contradictions; and the assumption itself introduces other contradictions; for the conceptions of extension composed of unextended elements, and of attraction and repulsion out of time and space, are in appearance no less contradictory than those which they pretend to explain, and labour under the additional difficulty that they are not even apparently warranted by experience. The real world of Herbart is thus reduced to the condition of an occult cause,—an *ens rationis*,—which might perhaps be shown to exist had we the faculties requisite for discerning it; but which, upon the same supposition, might equally be shown not to exist; and which, to our present faculties, is encumbered with apparent contradictions which render the latter conclusion the more probable of the two.

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philosophy. "In der That," he continues, "was können wir Anderes wollen, wenn wir über die Natur philosophiren, als das intelligibile Wesen der Natur, die zeugenden Ideen derselben, aus dem Innern unseres Geistes denkend zu reproduciren? (Hegel's *Werke*, vol. vii., Editor's Preface.)

[1] Das Seyn, das unbestimmte Unmittelbare ist in der That Nichts, und nicht mehr noch weniger als Nichts. . . . . Nichts ist dieselbe Bestimmung, oder vielmehr Bestimmungslosigkeit, und damit überhaupt dasselbe, was das reine Seyn ist." (Hegel, *Logik*, b. i., chap. i. Cf. *Encyklopädie*, sect. 87).

[2] Das Nichts ist als dieses unmittelbare, sich selbstgleiche, ebenso umgekehrt dasselbe, was das Seyn ist. Die wahrheit des Seyns, so wie des Nichts, ist daher die Einheit beider; diese Einheit ist das *Werden*." *Encykl.*, sect. 88. Cf. *Logik*, b. i., c. i.

[3] See the criticism of Trendelenburg, *Logische Untersuchungen*, vol. i., c. ii.

[4] "Die Metaphysik hat keine andre Bestimmung, als die nämlichen Begriffe, welche die Erfahrung ihr aufdringt, denkbar zu machen." *Lehrbuch zur Einleitung in die Philosophie*, sec. 149.

[5] "Herbart," says Trendelenburg, "has recourse, on the one side, to the Eleatics, and, on the other, to Leibnitz. From the former he acknowledges the pure conception of existence, but denies that existence is one. From the latter he accepts the plurality of existences, but refuses to endow the monads with a plurality of attributes." (*Ueber Herbart's Metaphysik*, p. 5.)

The theory solves none of the difficulties which give rise to it, but only conjectures that, under certain possible conditions of superhuman knowledge, they might be soluble;—a very legitimate position, if it were proposed as resting, not on reason, but on faith—not as explaining difficulties, but as bidding us rest content without explanation—not as the basis of a theory, but as a reason why theories are inadmissible. Let us grant, for the moment, Herbart's assertion that our intuition of objects in space and time is at variance with the laws of thought. It is no solution of the contradiction to reply that there may possibly be a superhuman intuition of objects out of space and time, and that, if we had such an intuition, there might perhaps be no variance. For we do not know that such an intuition is possible; and we do not know that, if it were possible, it might not present still greater variance. And so long as there is variance, what right has one of the adverse faculties of our nature to demand the submission of the other? Why should experience give way to thought, rather than thought to experience? "Which is the wiser here—justice or iniquity?" Which element of our nature testifies to the real, and which to the phenomenal?

OF THE PHILOSOPHY OF THE ABSOLUTE IN GENERAL.

This brief survey of the principal ontological systems of modern Germany, the only country in which the study of ontology proper has been zealously pursued in recent times, may, it is hoped, be of some use in clearing the field of discussion, and in bringing the great problem of philosophy under certain definite conditions, under which alone its solution can be attempted with a reasonable hope of success. In abstruse speculations of this character, we learn almost as much from the chart which tells us of rocks and shoals to be avoided, as from the compass which points out the direction in which we ought to steer; and the study of the philosophy of the absolute is at least serviceable in eliminating elements foreign to the investigation of the truth, and in teaching us, as Hegel himself said of the Newtonian optics, the manner in which metaphysical inquiries ought not to be pursued. Various and conflicting as are the theories of modern German philosophy, one common error may be detected as pervading all of them,—that of identifying reality with the absolute or unconditioned. Instead of examining the conception of the real as it is formed under the necessary conditions of human thought, and inquiring what is the object which corresponds to the conception so conditioned, they assume at the outset that real existence means existence dependent upon nothing but itself, and that the conception of real existence is a conception determined by no antecedent. Ontology is thus the absolute knowledge of absolute being; and, from this point of view, being and knowledge are necessarily one and the same thing; for if the object known is distinct from the act of knowing, the latter, to be valid, must conform itself to the nature of the former, and thus becomes relative and subject to conditions. Absolute knowledge is thus possible only on the condition that the mind, in the act of thought, creates the objects about which it thinks;—or rather, that the act of thought itself creates its own object and subject; for we clearly renounce *in limine* all pretension to absolute knowledge, if we admit that the act of knowing is in any degree dependent on the prior constitution either of a mind which thinks or of a thing about which it thinks. The philosophy of the absolute thus admits of a twofold refutation;—in the consequences to which it leads, and in the premises from which it starts. In its consequences it admits of no alternatives but atheism or pantheism;—atheism, if the absolute reality or creative thought is identified with myself;—pantheism, if it is identified with anything beyond myself. Subjective absolutism, or *egoism*, postulates self as the primitive reality on which all things depend, and acknowledges no God distinct from self and its modifications. Objective absolutism regards personality itself as a phenomenal manifestation of some higher reality, which alone is truly existent, and to which it gives the name, but not the nature, of God. Religion is equally annihilated under both suppositions; for if there is no God, whom are we to worship; and if all things are God, who is to worship him? Morality is equally annihilated under both suppositions; for if I am the absolute, I create my own moral duties, and cannot be required to conform to any standard independent of myself; and if I am a mode of the Divine Being, my actions flow from the self-determinations of the Deity, and are all equally necessary and equally divine. The premises from which these consequences issue are equally untenable with the consequences themselves. The primary testimony of consciousness affirms the distinct existence of an *ego* and a *non-ego*, related to and limiting each other. I know myself as existing in the midst of certain phenomena, which I did not create, and can only partially control. Pantheism contradicts the first element of consciousness, by denying the real existence of myself. Egoism contradicts the second element, by denying the real existence of anything distinct from myself. But if the testimony of consciousness on this point is false, how can I assume that it is true in any secondary and derived modification? How do I know that the very language of the philosopher of the absolute means what it appears to mean, or that my conviction of the truth of his system is not itself an evidence of its falsehood? Nay, how do I know that there is any philosophy of the absolute at all, or that the book in which, seeming to be myself, I seem to read it, has any contents, or communicates any knowledge, or is addressed to any reader?

OF THE CONDITIONS NECESSARY TO THE EXISTENCE OF ONTOLOGY.

Philosophy commences with doubt; and doubt is a state of consciousness. It is necessary, therefore, that the object of ontology, as a branch of philosophy, should be one to whose existence, at least in idea, consciousness bears positive testimony. This is not the case with the unconditioned, to the existence of which consciousness only negatively testifies, in so far as contradictory notions naturally suggest each other. The conceivable suggests the inconceivable; the real, the unreal; the possible, the impossible; and the conditioned, the unconditioned. To assume, from this suggestion alone, that we have a distinct conception of the unconditioned, or that there is a distinct reality answering to, or identical with, that conception, is as unwarrantable as to assume, on the same grounds, the reality of the unreal or the conceivability of the inconceivable. Thought is positive in so far as it represents an actual intuition; and two opposite objects, which can be both presented intuitively, may be both conceived reflectively, whether the terms by which the conceptions are denoted are positive or negative, contrary or contradictory. But, without a corresponding intuition, positive thought is impossible; and the intellectual intuition of Schelling is thus a necessary condition of the existence of any philosophy of the absolute. Unfortunately for the absolute, the intellectual intuition is a state of mind to whose existence consciousness does not and cannot testify;—nay, which it distinctly and positively declares to be impossible.

It is thus indispensable for the metaphysician, before commencing an inquiry into the nature of the real, to ask what is the actual conception of the real which consciousness furnishes; and what is the evidence on which we assert the existence of a corresponding object. It may be that the facts of consciousness present nothing but phenomena and that the real is merely suggested by language as the negation of the phenomenal; or it may be that some of the facts of consciousness exhibit certain characteristics, which indicate a higher amount of reality than can be assigned to others. Is the notion of the real positive or negative? and if it is positive, in what acts of consciousness do we find the corresponding intuition? When we have answered these questions, we shall have succeeded at least in confining the problem of ontology within definite limits: we shall have indicated the field of search, if we do not go so far as to discern the object. But the testimony of consciousness is clearer on the negative side than on the positive. It will assist our inquiry considerably if we can first ascertain, from the decisive evidence of consciousness, what the real of which we are in pursuit *is not.*

OF THEORIES OF THE REAL NOT FOUNDED ON CONSCIOUSNESS.

In the first place, the real of consciousness is not the Kantian *ding an sich*, or thing as it exists in its own nature, out of all relation to the human mode of perceiving it. Consciousness is given to us as the product of two factors, on both of which it is equally dependent,—the constitution of the person apprehending, and that of the thing apprehended. If either of these were changed, the result might be something totally different from its present appearance. In mathematical language, the result of consciousness is a *function* of the subject and the object together, and must be regarded as variable with the variation of either. To attain to a knowledge of a thing in itself out of relation to our faculties, it would be necessary to apprehend the thing with a new set of faculties, retaining at the same time a perfect recollection of our former mental constitution and its results, in order to separate what is relative and dependent on the existing constitution of the human mind from what is absolute and common to other orders of intelligent beings. It is manifest, therefore, that the real, in this sense of the term, represents nothing which can by any possibility be presented in consciousness.

In the second place, the real of consciousness is not the absolute which has reigned supreme in German philosophy since the time of Kant;—that is to say, an unconditioned first being, which exists in and by itself, and does not imply the prior or simultaneous existence of anything else. This has been already shown in our previous remarks on this theory, which exhibit its antagonism to the primitive dualism of consciousness, in which *self* and not-*self* mutually imply each other, and, consequently, in which neither of them is the absolute. It is also sufficiently shown by the admission of the absolutist philosophers themselves, who, by basing their systems on a supposed form of knowledge beyond, and even contradictory to, consciousness, virtually confess that the absolute has no existence in consciousness. The contempt with which the majority of German critics almost invariably mention the name of dualism, is a proof, among many others, of the necessity which they feel of lifting the standard of philosophy in opposition to the authority of consciousness.

In the third place, the real of consciousness is not the *substance* or *matter* of an earlier school of metaphysicians; that is to say, the insensible substratum of sensible qualities, viewed by itself, apart from those attributes by which it is made known to experience. We may not commence our inquiries with the assumption that the shape, the colour, the smell, and other sensible qualities of a rose are one thing, and that the rose itself, the thing possessing the qualities, is another. "The idea," says Locke, "to which we give the general name *substance*, being nothing but the supposed, but unknown support of those qualities we find existing, which we imagine cannot subsist *sine re substante*, without something to support them we call that support *substantia;* which, according to the true import of the word, is, in plain English, *standing under* or *upholding*."[1] "I perceive," says Reid, "in a billiard ball, figure, colour, and motion; but the ball is not figure, nor is it colour, nor motion, nor all these taken together; it is something that has figure, and colour, and motion. This is a dictate of nature, and the belief of all mankind."[2] Without attempting at present to anticipate the necessary inquiry into the validity of that law of belief which apparently compels us to refer a plurality of attributes to a single subject, we may safely assert that the notion of such a subject, as a being distinct from its attributes, is utterly empty and meaningless; and that no such being can be the object of metaphysical research. Consciousness does not testify that such a being exists or is conceivable;—nay, such a testimony would be impossible without the annihilation of consciousness itself. For consciousness is possible only under the condition of difference. I can be conscious of an object, as such, only by being conscious of it as distinguished from other objects; and this distinction is only possible by means of the special attributes which the object possesses. Deprive the billiard ball of its figure and colour, and all other sensible qualities, and do the same to the table on which it stands; and how is the ball to be distinguished from the table? The residuum, if there is any, is neither the ball as a ball, nor the table as a table, nor any one thing as distinguishable from any other thing, nor an object of consciousness as distinguished from the subject. It is the vague and empty notion of being in general which is no being in particular,—pure existence, which is identical, so far as human thought is concerned, with pure nothing. Things can be distinguished from each other only by their attributes; and to be conscious of a thing apart from its attributes, is to be conscious of a difference with no difference to be conscious of. "The knowledge of pure substance distinct from its qualities," says M. Cousin, "is impossible, for the simple reason that no such substance exists. Every real being is of such or such a kind; it is either this or that. If it is real, it is determinate; and to be determinate is to possess certain manners of being, transitory and accidental, or constant and essential. The knowledge of being in itself is therefore not only forbidden to the human mind, but is contrary to the nature of things.[3] Whether the existence of a thing distinct from any and all of its attributes be, as Reid says, a dictate of nature or not; at any rate, in the instance which he adduces, it is not *presented* as a fact of consciousness, but *inferred* from the presence of the attributes; and, in maintaining the veracity of the facts of consciousness themselves, we do not therefore maintain the validity of all the inferences to which those facts appear to lead. What is the exact fact upon which this inference is grounded, the principle on which it is made, and the amount of credit due to it, we shall endeavour to show hereafter by an examination of consciousness itself. For the present, it is sufficient to say, that the fact, whatever it may be, is not a direct cognition of the existence of a substratum of material attributes.

It thus appears that the celebrated hypothesis of Bishop Berkeley, so far as it merely denies the existence of matter, is not in any way contrary to common sense (if by common sense is meant the direct evidence of consciousness); inasmuch as it only denies that concerning which consciousness offers no evidence at all. For *matter*, in Berkeley's sense, does not mean anything which can be perceived by the senses; but only, as Locke defines it, "the supposed, but unknown support of those qualities we find existing." "I do not argue," says the bishop, "against the existence of any one thing that we can apprehend either by sense or reflection. That the things I see with mine eyes and touch with my hands do exist, really exist, I make not the least question. . . . If the word *substance* be taken, in the vulgar sense, for a combination of sensible qualities, such as extension, solidity, weight, and the like, this we cannot be accused of taking away. But if it be taken in a philosophic sense, for the *support of* accidents or *qualities without the mind*, then, indeed, I acknowledge that we take it away, if one can be said to take away that which never had any existence, not even in the imagination."[1] And had Berkeley confined himself to the sceptical side of the question,—had he contented himself with maintaining that we have no evidence for asserting that matter, in this sense of the term, has any existence,—he would have said no more than the testimony of consciousness fully warrants. But when he went a step beyond this, and not only doubted the existence of matter, but asserted its non-existence, he transcended the evidence of consciousness on the negative side, as much as his opponents did on the positive. If consciousness says nothing about the existence of matter at all, we are equally incompetent to affirm or to deny. The sceptic, so long as he remains a mere sceptic, is unassailable: the dogmatist, whether in affirmation or in negation, equally dogmatizes on the ground of his own ignorance. But, in admitting one portion of Berkeley's theory as perfectly tenable, we do not therefore accept his entire system of idealism. It is quite possible to take an intermediate course;—to admit, with Berkeley, that we have no right to assert the existence of any other kind of matter than that which is presented in consciousness; but to deny his other main position, that we are conscious only of our own ideas. If, in any mode of consciousness whatever, an external object is *directly presented* as existing in relation to me, that object, though composed of sensible qualities only, is given as a material substance, existing as a distinct reality, and not merely as a mode of my own mind. And, to this extent, the arguments of Reid and his followers, however inaccurate their analysis of consciousness may be in some of its details, are valid against idealism.

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[1] *Essay*, b. ii., chap. xxiii., sect. 2.

[2] *Intellectual Powers*, Essay ii., chap. xix.

[3] *Histoire de la Philosophie Morale au dix-huitième siècle*, Leçon xii.

The antagonism of the Scottish philosophers to the theory of Berkeley, arose more on account of its supposed remote consequences, than of its immediate conclusions. It was supposed to furnish a legitimate foundation for the scepticism of Hume, who argued against the existence of mind on the same grounds on which Berkeley had denied the existence of matter. Within myself, he urged, I am conscious only of impressions and ideas, as in external sensation I am conscious only of extension, figure, and so forth. The substance called *mind* may therefore be a mere fiction, imagined for the support of the internal states of which I am conscious, just as the substance called *matter* is imagined for the support of sensible qualities.[2] But, in order that this conclusion may legitimately follow from Berkeley's principles, we must concede an additional premise, which Berkeley by no means admits,[3] namely, that the evidence of consciousness in relation to matter and to mind is of precisely the same character. If, as Locke maintained, and as the antagonists of Hume allowed, we have no immediate consciousness of *self*, but only of its several modes, the sceptical conclusion necessarily follows; and Hume, as a professed sceptic, had nothing to do with correcting the received dogmas of philosophy, but only with exhibiting their ultimate consequences. Those consequences can only be refuted if, by a more exact analysis of the facts of consciousness, it can be shown that the personal self, as the one permanent subject of various successive modes, is directly presented in intuition along with its several affections. But this analysis neither Reid nor Stewart attempted; and the consequence was, that in their hands the sceptical argument remained, in its main positions, unrefuted.

In the fourth place, it may be shown, by the same considerations, that the real of consciousness is not the *first matter* of the peripatetic philosophy; that is to say, an universal substratum, common to all objects of sense, and subject to the changes of form which constitute this or that definite object.[4] This first matter is, indeed, nothing more than the *matter* of the last hypothesis, stripped of some of its more glaring incongruities, but not thereby made more accessible to consciousness. The theory of a first matter avoids, indeed, the absurdity of saying that any one particular thing, such as a billiard-ball, is something distinct from its own sensible qualities; but the supposition which it assumes instead,—that of a subject which is all things in capacity, and nothing actually,—is only a more logical negation of all difference, and therefore of all consciousness; for consciousness is possible only through difference. The psychological value of the axiom on which this theory apparently rests,—namely, that all things are changed, and nothing created or destroyed; so that the quantity of real matter in the world can never be conceived as increased or diminished,—has been examined in a previous passage; but even if a greater amount of truth be assigned to this principle than our previous remarks have accorded to it,—whether it be regarded as a law, or merely as an impotence of mind,—it is at any rate a phenomenon of mind and not of matter: it can be explained on psychological grounds only; and it presents no fact in the constitution of things, but only a mode of our conceiving them. Unless the truth of that conception can be guaranteed by a positive intuition of its object, which in this case is impossible, we are not warranted in elevating a mere consciousness of the limit of our own powers of thought into a measure of the conditions of all possible existence.

In the fifth place, the real of consciousness, so far as the material world is concerned, is not to be found in the chemical elements into which bodies may be ultimately resolved. It does not express any metaphysical distinction to say that what appears to be air is in reality oxygen and nitrogen; or that water, ice, and steam are but different appearances of the same elementary particles. This is perfectly true as a physical fact; but it contributes nothing towards the solution of any problem of metaphysics. The chemical element, as well as the compound, is an object of sense, and its presence must be tested by sensible criteria. If, then, there is any apparent antagonism between sense and thought;—if there is any room for doubt whether what sense regards as a reality independent of myself, thought may not resolve into a transitory affection of my own mind,—such a doubt is equally possible, whether the object of sense be more or less minute, whether its presence be manifested by the immediate evidence of sight, or by the indirect test of experiment. In one respect, indeed, the chemical element has less of the character of a real object than the compound into which it enters; inasmuch as its presence must frequently be inferred rather than perceived,—detected in its effects on something else, not in its own proper nature. There will still remain the question, What is the *thing itself*, as distinguished from the test by which we discover its presence on particular occasions?

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[1] *Principles of Human Knowledge*, xxxv., xxxvii.

[2] See *Treatise of Human Nature*, part iv., sects. 5, 6.

[3] In the third dialogue between Hylas and Philonous, Berkeley expressly says:—"I know or am conscious of my own being; and that I myself am not my ideas, but somewhat else,—a thinking, active principle, that perceives, knows, wills, and operates about ideas." Here he distinctly denies the position of Locke, and refutes by anticipation Hume's deduction from his own principles.

[4] Aristotle, *Phys. Ausc.* i. 7. Compare Harris, *Philosophical Arrangements*, chap. iv.

In like manner it may be shown, lastly, that the metaphysical question is in no way simplified by any theory, such as that of Boscovich, which regards the senses as immediately cognisant, not of matter in itself, but only of the attractive and repulsive forces which one particle exercises on another. For the ultimate atoms of matter being, upon this hypothesis, never presented in consciousness, could never have given rise to the distinction, which apparently exists in our minds, between the real and the phenomenal. That distinction must be suggested by something of which we are conscious; and if we are conscious only of forces, it must depend upon some difference in the forces themselves. The forces thus inherit all the metaphysical difficulties of the matter which they represent; and we must still have recourse to the analysis of consciousness itself, to determine in what manner the metaphysical doubt could have originated, and what are the data available for its solution. To inquire into the truth and value of Boscovich's theory itself, is a question of physics, not of metaphysics.

OF THE REAL AS GIVEN IN CONSCIOUSNESS.

Having thus simplified the problem by the elimination of foreign elements, we have next to inquire what is the positive testimony of consciousness itself, as regards the existence of a distinction between the phenomenal and the real, and how far the distinction thus indicated will enable us to ascertain the nature of the respective objects to which it refers? for that the distinction has a foundation in consciousness, however much its meaning may have been misinterpreted, is manifest, if it were only from the existence of such misinterpretation. Rightly or wrongly, men have thought that such a distinction exists:—why they have thought so, the examination of consciousness itself can alone explain.

It is necessary, in the first place, to determine clearly what it is of which we are in search. We must know what is meant by *reality*, and what by *appearance*, before we can classify the facts of consciousness as indicating one or the other. For here there is an ambiguity which, if not cleared up at the outset, may confuse the whole subsequent inquiry. It is one thing to distinguish between the real and the phenomenal, as exhibited in the facts of consciousness themselves: it is another to determine what are really facts of consciousness and what are not. There are judgments which are sometimes supposed to rest on the immediate testimony of consciousness, but which, rightly interpreted, are inferences only remotely suggested by it. I think I see a friend at a distance: on a nearer approach he turns out to be a stranger. Here the apparent testimony of sight is in reality an inference pursued through many successive stages. In the first place, I am not really conscious by sight of the presence of a distant object at all, but infer its presence from the consciousness of certain affections of the organ of vision. In the second place, when I have projected by association the impression of a certain coloured surface into a space exterior to my organism, I do not thereby know that this surface is a man: this is a second inference, implying memory, and comparison, and recognition of certain specific attributes. In the third place, when I have so far obliterated these connecting links as to fancy that I see a man, I do not thereby know a friend from a stranger: this is another act of inference, implying memory of certain individual features, and comparison of them with my present impression. Yet all this is performed with such rapidity as to appear an immediate act of perception; and John or Thomas is, in ordinary apprehension, as much an object of sight as redness or blueness.

This distinction is irrelevant to our present inquiry. When we ask how reality and appearance may be distinguished from each other by the testimony of consciousness itself, it is to be supposed that we have already ascertained what are facts of consciousness, and what are not. But this being granted, a second ground of distinction presents itself. Every fact of consciousness, as such, guarantees the existence of its object, so long as it is actually present. But there are some facts of consciousness which are instinctively acknowledged to indicate only the relative and transitory existence of their objects, and others which are supposed to imply something more than this. An affection of the nervous organism exists only as it is felt, and ceases to exist when it is felt no longer; it has no independent existence of its own, but is a mode of my being, created by the act of consciousness, and ending along with it. But, on the other hand, all men instinctively believe, and will believe in spite of the arguments of the idealist, that we are immediately conscious of an external world, and that that world exists when we are not conscious of it. The impression which the sight of a mountain makes on my optic nerve is destroyed when I shut my eyes; but no man believes that the mountain is destroyed along with it. Consciousness testifies that we have this belief; and on this testimony metaphysical systems have been built, which, however widely some of them may have wandered from the true solution of the question, all alike prove that the question itself is suggested by consciousness.

This latter distinction properly belongs to ontology; the former to psychology; though, in actual discussion, the two have been frequently mixed together. Among the facts, or supposed facts, of consciousness, the impressions of the senses, from the one or the other of the above points of view, have been, almost from the commencement of philosophy, especially noted as indicating appearance and not reality. The following may be cited among the arguments adduced in proof of this position:—In the first place, sensation is but the result of a transitory relation between the organ and its object:—colour, for example, exists neither in the eye by itself nor in the visible object by itself, but is produced by their temporary juxtaposition.[1] In the second place, the same object presents different impressions to the same sense, according to the condition of the sensitive organ itself.[2] A man with the jaundice sees all objects as yellow: one afflicted with colour-blindness sees as blue that which, in a healthy state of the eyesight, appears as red: to a diseased palate the taste appears bitter, which a sound palate receives as sweet. But if the abnormal state of the organs of sense produces an impression which is acknowledged to be apparent only, why should the normal state be regarded as giving a knowledge of reality? If the unusual appearance is wholly dependent on an extraordinary condition of the organism, is not the usual appearance equally dependent on the ordinary condition? And how can either of them represent a real object, which in itself is unaffected by any change in the condition of the person perceiving it? In the third place, the same object presents a different quality to different senses. An apple, for instance, is perceived by the sight as yellow, by the taste as sweet, by the smell as fragrant.[3] If the several objects of sense are distinct realities, the apple is not one but many; if, on the contrary, the apple is, as we are compelled to conceive it, one, it follows that the impressions of the senses are not real things, but unreal appearances of that which in itself is not diverse but uniform. In the fourth place, the same object presents different impressions to the same sense, according to the different circumstances in which it is placed. A tower, which at one distance appears to the eye as square, at another seems to be round; at one distance it appears larger, at another smaller.[1] But the tower itself undergoes no change of figure or size. It is manifest, therefore, that one at least of these impressions exhibits not that which is, but that which seems to be; and unless some reason can be assigned for preferring one to the other, we may reasonably conclude that both do so. In the fifth place, the sensible impression may take place without the presence of any external object by which it can be caused. Such is the case in dreams and spectral illusions, in which we appear to see, with all the vividness of actual sight, things which have no existence except in our own imagination.[2] But if this actually takes place in some instances, why may it not take place in all? By what criterion are we to distinguish the true from the false; or how can we be sure that the senses present to us real objects, when their testimony can be so well counterfeited by mere phantoms?

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[1] Plato, *Theætetus*, pp. 153, 156.

[2] Plato, *Theætetus*, p. 159. Pyrrho *apud* Laert. ix. 82. Sext. Empir. *Pyrrh. Hyp.* i. 100.

[3] Pyrrho *apud* Laert. ix. 81. Sext. Empir. *Pyrrh. Hyp.* i. 90. Cf. Plato, *Sophistes*, p. 251.

These difficulties are considerably increased, if we adopt, with the vast majority of philosophers in ancient and modern times, the representative theory of perception, and maintain that like can only take cognisance of like, and therefore that the mind, which is the seat of all consciousness, perceives through the senses, not material objects, but only its own ideas, by which material objects are represented. For how are we to guarantee that the idea has any resemblance to the object which it represents? To know that two things resemble each other, I must compare them together. But the material world, according to this hypothesis, is never perceived at all, and therefore cannot be compared with its supposed representative.[3] And the ideas, whether regarded as immaterial objects distinct from the percipient mind, or as modifications of the mind itself, are called into existence in and by the act of perception, and have no existence except when they are perceived[4]. On this hypothesis we are not warranted in affirming the existence of that of which we are never conscious; and the conclusion to which it naturally leads is that which denies the existence of matter, and makes the whole external world a series of phenomena dependent on the action of the mind.

Such are a few of the grounds on which philosophers, in all ages, have maintained that the senses are the sources of deception, not of truth, and are conversant with appearance only, not with reality. And a more accurate acquaintance with the physiology of the sensitive organs confirms the latter part of this verdict, though it furnishes a defence against the former. The senses do not deceive us with regard to an external world, because, rightly interpreted, they tell us nothing at all about it. We are deceived, not in the facts to which the senses bear witness, but in the inferences which we draw from them. The colour and the savour appear different in different states of health, because, in truth, as affections of the nerves of sight and taste, they are different in different conditions of the organism. The sensible qualities of a body are in fact, as they appear to be, distinct affections of the several organs; and it is not sense which tells us that these different qualities constitute a single thing. The tower, which appears to change its shape and size as we approach it, is not in reality the same visible object at any two steps of our progress. What we actually see at any moment is nothing but the rays of light in contact with the organ of vision; and every change of position places us in contact with a different complement of rays. The dream or the spectral apparition is as veritable an affection of the optic nerve as the commonest impression of sight; and we err only in inferring the presence of an external object, of which the sight itself in no case tells us anything. But, while we may thus defend the senses against the charge of deception, we are in another respect compelled to acknowledge that their objects are not things but phenomena. An affection of the nerves of sense is not a distinct reality existing independently of myself: it is but a transitory mode of my own consciousness, which exists only while I am conscious of it. A real object is not dependent for its being and properties on my being aware of them: it has an existence and attributes of its own, whether I am at this moment conscious of them or not. But the proper objects of the bodily senses,—colours, sounds, flavours, savours, and tactual sensations,—exist, as such, only in my consciousness, and cease to exist when my consciousness ceases. They may be caused by some permanent reality or realities independent of me; but of the existence and nature of this reality the senses tell us nothing.

It is not, therefore, to the senses, properly so called, that we must look for the distinction between reality and appearance in the material world. The only attribute of matter which these make known to us is the extension of our own organism; and, with regard to this, the distinction in question has no place. Were the senses the only channels of communication between mind and matter, we could never have thought of asking how much of that communication is real, and how much phenomenal. Whether my nervous organism exists, as an extended substance, out of the act of perception in which its extension is manifested, is a question which could never have arisen from the act of sensitive perception alone; for, in order to ask such a question, I must first be enabled to separate in thought the object of perception from the act of perceiving it, and thus to constitute it an extra-organic reality; and to do this, the extra-organic world must first be presented in some form of intuition. Apart from the associations which the senses derive from this intuition, all modes of perception would be regarded as equally real, or equally phenomenal; for the real and the phenomenal could never have been conceived as contrasted with each other.

The analysis of the facts of external intuition, which has been given in the preceding pages, will enable us to ascertain the meaning of the distinction, and to determine the limits within which the question which it raises can be intelligibly answered. Resistance to the locomotive energy is the only mode of consciousness which directly tells us of the existence of an external world; and the attributes which are made known to us in that relation are the only ones which are directly given as constituting a material reality. These attributes are *occupation of space*, implying size and figure; and *resistance*, more or less stubborn, implying the impossibility of two bodies occupying the same place. And these are, in fact, the tests of reality to which we instinctively appeal on all occasions, even where the circumstances of the case do not permit their actual application. A body is necessarily conceived as in space, and an external body as in a space exterior to our organism. This implies the occupation of a portion of space, which is size, and the limitation by surrounding space, which is figure. But I may not be able, in particular cases, to verify this conception by any empirical test. I may be placed blindfold against a wall, of which I am not able to feel the extremities. I cannot therefore pronounce empircally, either directly, from contact, or indirectly, from sight, that it is limited in its length and height, or that it is square, or circular, or of any other known figure. But I am compelled to believe that it has a definite size and figure, and that I should be able to feel them if I were in some other position. Again, a volume of smoke may offer no perceptible resistance to the motion of my arm. But here, again, I am compelled to believe that it offers some resistance, which, with more acute faculties, I should be able to perceive; for I cannot conceive myself as placing my hand in the midst of the smoke without displacing the particles with which it comes in contact. The atmosphere, whose ordinary pressure, like the music of the spheres, is unperceived because it is always present, exerts, as is well known, a resistance as great as 15lb. on the square inch; and wherever a body penetrates, it produces during its occupation an atmospheric vacuum. A body, then, is *presented* as real when it actually offers resistance to the locomotive effort: it is *represented* as real when we believe that it would resist if we were in a position to make the attempt. By this test the objects of the senses are instinctively, and often unconsciously, judged. The visible and tangible impressions, which are usually accompanied by the apprehension of resistance, are regarded, first, as signs of the presence of a real object, and afterwards as real objects themselves; and the sight of the sun in the sky gives us a conviction of its independent existence, as firm as if we could feel it supporting our tread. But that this conviction is indirect, not immediate,—the result of association, not of original intuition,—is evident from the fact that, when the association is broken, the belief in the reality of the object is instantaneously destroyed. Let an object be given as visible but unresisting, and it is at once acknowledged to exist in appearance only, and not in truth:—

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[1] Pyrrho *apud* Laert. ix. 85. Sext Empir. *Pyrrh. Hyp.* i. 118. Hume, *Essay on the Academical Philosophy.*

[2] Plato, *Theætetus*, p. 157. Pyrrho *apud* Laert. ix. 82. Sext. Empir. *Pyrrh. Hyp.* i. 104. We have not noticed those arguments which are drawn from the comparison of one man with another, or of men with brutes. We are treating only of the distinctions indicated by consciousness; and we have no access to the consciousness of any other creature than ourselves.

[3] Sext. Empir. *Pyrrh. Hyp.* ii. 74. Berkeley, *Human Knowledge*, part i., sect. 8; Cousin, *Cours de* 1829, Leçon 21.

[4] Berkeley, *Human Knowledge*, part i., sect. 3; *Dialogues between Hylas and Philonous*, Dial. ii. Berkeley goes so far as to deduce from this position an argument for the being of God; on the ground that the world cannot have a continuous existence, except in some continuously percipient mind.

> "Ter conatus ibi collo dare brachia circum;
> Ter frustra comprensa manus effugit imago,
> Par levibus ventis volucrique simillima somno."[1]

These lines express the instinctive belief of all mankind in the true criterion of material reality,—a belief which is justified and explained by the testimony of consciousness read by the light of psychological research.

OF THE REAL IN COSMOLOGY.

The above observations may furnish materials for a criticism of that branch of metaphysics known as cosmology, or the ontology of the material world. They will serve to point out what are the facts of consciousness which give rise to the conception of such a science, and what are the limits within which that conception can be realized. The conception of reality in material objects is derived from the consciousness of extension and resistance in conjunction; and the philosophy of the real, in this department, has no legitimate field beyond the several conditions and relations of these attributes, as presented in various modes of experience. Its object, therefore, is not a supersensible world lying beyond the facts of consciousness, but the sensible world, in those properties which are primarily and directly made known to us as modes of resistance to the locomotive energy, such as gravity, cohesion, repulsion, motion, and their various subdivisions. Its method is not demonstrative, except in so far as the mathematical attributes of pure extension are applicable hypothetically to extension in conjunction with resistance. In the verification of this hypothesis in any particular case, and in those researches which belong to its own province, it deals with matters of fact; and matters of fact cannot, as such, be matters of demonstration. This limitation is confirmed, on further consideration, by those facts of consciousness which at first seem to point to a contrary conclusion,—the necessary principles and reasonings of geometry. For these have been shown to depend on certain forms or conditions of experience, derived from the constitution of the mind itself, and to imply the existence of nothing but a conscious mind, modified in a certain manner. Of the real existence of its object, geometrical reasoning tells us nothing; but only that, on the supposition of its existence, certain properties may be proved to belong to it;—the proof, however, being equally valid whether the supposed existence be in fact or merely in imagination. The test of the real existence of matter is resistance, without which extension alone is not conceived as an external reality: and to the modes of resistance, as such, the demonstrations of geometry are not applicable.

The above conception of cosmology is, it must be confessed, very different from that which metaphysicians in general have attempted to realize. Indeed it may be regarded by some as indicating rather a physical than a metaphysical system; and this charge must be admitted, if the science of physics is viewed in its most general extent, as embracing the universal properties of matter in general, as well as the special characteristics of this or that body.[2] But the fault, if it be one, lies, not in the conception, but in the facts of human nature on which it is founded. If our faculties are so limited as to present us only with physical attributes of matter, the metaphysics of matter can contain nothing more than the principles and results of physics in their most general extent. We may regret, if we please, the limitation, and sigh for a knowledge of a hyperphysical world; but our faculties do not convey such a knowledge, and all our sighing will not make them do so. The limitation is one which our Creator has thought fit to impose upon us, and, regret it as we may, we cannot escape from it.

But a philosophy which fails to solve, and even refuses to grapple with, certain problems, may vindicate itself by explaining why they are insoluble. Before quitting the subject of cosmology, it is necessary to point out in what respects the above sketch falls short of the highest conception of a metaphysical system, and why it does so. In the first place, it starts from the apprehension of matter as extended, and does not attempt to solve the higher difficulty involved in the notion of extension itself. Extension cannot be regarded as the unit of material reality; for it is dependent on a juxtaposition of parts whose reality cannot consist merely in their combination. Extension is a relation between parts, as exterior to each other; and a relation implies things related, which must be real in themselves, else no reality could result from their combination. This difficulty, with all the accompanying paradoxes involved in the infinite divisibility of matter, is abandoned as insoluble; and it is obvious why it is so. If space is a necessary form of intuition, involved in the laws of our mental constitution, it follows that, to explain the generation of space itself, we must go out of our constitution. To conceive the ultimate reality on which extension depends, I must conceive the non-extended becoming extended,—a conception which is impossible; first, because thought is only operative within the limits of possible intuition, and we can have no intuition of unextended matter; secondly, because, to conceive a relation between the unextended and the extended, I must be able to compare them together; and to do this I must be in and out of my mental constitution at the same moment. An ultimate unit of space is thus as inconceivable as a first instant of time; and for the same reason—because both space and time are necessary forms of intuition. In the second place, the riddle which has puzzled the metaphysicians of all ages still remains unanswered:—"How can the one be many, or the many one?" In other words, "How can a variety of attributes constitute a single object?" This problem also is insoluble; and for a like reason—because consciousness cannot account for its own laws. If consciousness is limited, the consciousness of that limit implies the existence of something of which we cannot think; and this is equally true of the limits of intuition and of those of thought. Now, it is a necessary condition of conception, as has been already shown, that its object must comprehend a plurality of attributes;—in other words, that thought is impossible except under the condition of diversity in unity.[1] To explain why this is so, would be to explain why our minds are constituted as they are; and this involves a criticism of the laws of thought themselves. But such a criticism manifestly destroys itself; for it can only be carried on by thought operating under the very laws whose validity is questioned. Whatever doubt, therefore, can be raised concerning the object of criticism must likewise affect the critical process itself. Wherever, therefore, we fix the limits of thought, something must remain inexplicable. From this we cannot escape, except by denying that thought has limits; and this denial again annihilates itself; for if thought has no limits, nothing is unthinkable; and if nothing is unthinkable, nothing is absurd; and if nothing is absurd, no system of philosophy is more reasonable than another, and the denial of limits is not more true than the assertion of them. In the third place, metaphysical philosophy is admitted to be concerned, not with matter as it is, but with matter as we conceive it; and this admission, too, is a necessary consequence of the laws of consciousness, in its manifestation, as a relation between a subject and an object. We cannot compare the object of consciousness with a thing of which we are not conscious; for comparison itself is an act of consciousness: we can only compare one object of consciousness with another,—the permanent with the transitory, the necessary with the contingent. There still remains the question, "Do things as they are resemble things as they are conceived by us?"—a question which we cannot answer, either in the affirmative or in the negative; for the denial, as much as the assertion, implies a comparison of the two.[2] If, then, *being* is interpreted to mean the absolute beyond consciousness, and *appearance* the relative within it (an interpretation, however, which is not warranted by the analysis of consciousness itself), it must be admitted that the philosophy of the material world, in its highest form, is not ontology, but phenomenology.

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[1] Virgil, *Æn.*, ii. 792.

[2] According to Aristotle (*De Anima*, i. 1), physical philosophy is concerned with the special operations and attributes of this or that body as such, (*περὶ ἅπανθ' ὅσα τοῦ τοιουδὶ σώματος καὶ τῆς τοιαύτης ὕλης ἔργα καὶ πάθη*). If this definition be accepted, the attributes common to all bodies may be properly referred to a more general branch of philosophy.

OF THE REAL IN PSYCHOLOGY.

This admission, however, cannot be extended to the second branch of the metaphysics of being, which deals with the internal consciousness and the personal self; for here the interpretation on which it depends is utterly untenable. Psychology, like cosmology, cannot transcend the limits of consciousness; but in psychology it cannot in any sense be maintained that the real is that of which we are not conscious. My own consciousness is not merely the test of my real existence, but it actually constitutes it. I exist in so far as I am a person; and I am a person in so far as I am conscious. Were it possible, which it is not, to conceive the human soul as a substance of which consciousness is only an accidental mode,—which may exist at one time in a conscious, and at another in an unconscious state,—such a soul could in no sense of the term be called *myself;* the various modes of its existence could in no sense be called *mine.* The Cartesian *cogito, ergo sum,* is so far from being, as its opponents have maintained, an illogical reasoning from a premise to its conclusion, that its only fault consists in assuming the appearance of a reasoning at all. My consciousness does not *prove* my existence, because it *is* my existence. Descartes does not intend, as Reid imagined,[3] to reason from the existence of thought to the existence of a mind or subject of thought: he intends to state wherein personal existence consists; and he rightly places it in consciousness.[4] The opinion of Locke,[5] that the soul does not always think, is tenable only as a part of that false psychology which regards the soul as a substance projected, as it were, out of consciousness, the unknown substratum imagined as the support of known accidents.[6] If I am never conscious of myself, but only of my ideas, I can, of course, pronounce nothing concerning the conditions of my real existence; but then, upon the same supposition, I could never have known that *I* am conscious, or that the ideas are *mine.* If there is nothing given in consciousness but ideas, there is no such thing as personal existence; but only a multitude of isolated ideas, each conscious of itself. Put the question in another form: ask what is the evidence that *I exist* at all; and I can only adduce the direct witness of consciousness. The existence of *myself* is a fact of consciousness, not an inference from it; for an *I* must be presupposed to make the inference. The unconscious substratum of possible ideas may be *a soul,* in some arbitrary and unmeaning definition of that term; but assuredly it is not *myself.* If we could suppose a human body growing up to maturity without consciousness, and a conscious principle afterwards infused into it, the body in its previous

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[1] See *ante*, p. 589.

[2] Kant maintains that the objects of our intuition *are not* in themselves as they appear to us. (*Kritik. der. r. V.*, Transc. Æsth., sect. 8.) Here, however, the critic becomes a dogmatist in negation, and contradicts his own fundamental hypothesis; for if things in themselves are absolutely unknown, how can we say whether they are like or unlike anything else?

[3] *Inquiry*, chap. i., sect. 3.

[4] See the dissertation of M. Cousin, "Sur le vrai sens du *cogito, ergo sum,*" printed in the earlier editions of the *Fragments Philosophiques*, and in vol. i., p. 27, of the collective edition of his works. The same position is well illustrated by Mr Veitch, in the introduction to his translation of the *Discours de la Méthode*, p. 22. See also *Principia*, p. i., sects. 8, 9, 53.

[5] *Essay*, b. ii. ch. i., sect. 10.

[6] Locke's assertion is but partially refuted by Leibnitz, (*Nouveaux Essais*, ii. 1.) who holds that, in sleep without dreams, the mind is in a state of obscure perception, not amounting to consciousness;—an opinion which is also maintained by Wolf, *Psychologia Rationalis*, sect. 59. But the opposite opinion, suggested by Aristotle, (*De Somno*, c. i., ἣ συμβαίνει μὲν ἀεὶ καθεύδουσιν ἐνυπνιάζειν, ἀλλ᾽ οὐ μνημονεύουσιν.)is adopted by some of the most eminent psychological and physiological writers of modern times, as confirmed both by *à priori* probability and by positive experience. (See Kant, *Anthropologie,* sects. 30, 36; Jouffroy, *Mélanges Philosophiques*, p. 290; Holland, *Chapters on Mental Physiology*, p. 80; Brodie, *Psychological Researches*, p. 147.) Some valuable remarks and illustrations of this position are contained in Sir W. Hamilton's unpublished Lectures on Metaphysics.

Ontology.

condition would be no more a part of myself than the limb which was amputated from me ten years ago, and which is now dissolved into its chemical elements. Yet the inquiry, how far personality is diminished by amputation or increased by corpulence, is not more irrelevant, than to ask when consciousness begins in the new-born infant, or in the fœtus in the womb. In so far as the rudiments of my body existed prior to the birth of consciousness, in so far they were not parts of myself: and I, as a person, had no existence. I hold that my personality is undiminished by the loss of a limb, simply because I am conscious that it is undiminished; and for the same reason I refuse to acknowledge that *I* existed in the rudimentary fœtus, or in the ovum, or in the spermatozoon, or in the organism of my remote ancestors.[1]

But when we place the personal existence in consciousness, it is necessary to distinguish between the accidents of consciousness and its essential constituents. A man who has lost his eyesight has in one sense less consciousness than he had before; he has lost that portion which consists in the sensations of vision. But his personality remains undiminished by the loss either of the bodily organ or of the affections of consciousness which that organ communicates. The same may be said of the other bodily senses; each of which may be conceived to be annihilated without any destruction of the personality of the conscious subject. This is the natural testimony of consciousness to the spirituality of man. We cannot help believing that the body and its organs, however necessary during the present life to certain modes of consciousness, however chronologically the occasion of the earliest development of consciousness in general, is yet no part of the conscious subject,—is not, in any sense of the term, *myself.* And this instinctive conviction of the untaught consciousness of mankind is further strengthened by all that science tells us of the constitution of the body and its organs. Of the animal body is emphatically true what Heraclitus and the general voice of philosophy after him declared of the objects of sense in general:[2]—it exists not, but is continually being produced; it no sooner comes into being than it ceases to be. At no two successive moments does it consist of exactly the same particles; and during the course of a long life, the entire system is many times destroyed and renewed again. Our whole physical existence is but a series of chemical changes; "the solid," to quote the words of a recent writer,[3] "melting into the liquid, the liquid congealing into the solid; whilst both stand so related to the air, which is the breath of life, that they are continually vaporising into gases." Yet amidst all these changes, the conscious subject, the personal self, continues one and unchanged. A similar distinction between the accidental and the essential must be made with regard to the internal consciousness: the matter of that consciousness is continually changing; while the form abides permanent and immutable: emotions, thoughts, volitions, succeed one another at every moment: the self,—feeling, thinking, willing,—is one and the same throughout. It is not necessary to my personal existence that I should feel joy or sorrow, anger or tranquillity; for the calm man of to-day is the same as the angry man of yesterday; and he who laughs to-day may weep to-morrow. Nay, more: not only is every special experience which constitutes the matter of consciousness alien to and separable from the personality of the subject; but even a portion of the form of consciousness must be regarded as having in this relation only a hypothetical and secondary necessity. The intuition of space, though necessarily accompanying every perception of matter, whether in our own organism or in the exterior world, is yet necessary only so long as we are in the body and conscious by the bodily senses. We cannot positively conceive a state of existence from which space is separated; yet, on the other hand, we are compelled to believe that existence in space is an attribute of body, and not of mind.

But when all these are set aside, there yet remain two conditions which I conceive as essential to my personal existence in every possible mode, and such as could not be removed without the destruction of myself as a conscious being. These two conditions are *time* and *free agency.* To consciousness, in its limited and human form of existence (of the divine consciousness we are not entitled to speak), it is essential that there should be a permanent subject with a succession of modifications. The consciousness of any object, as such, is only possible under the condition of change; and change is only possible under the condition of succession. Destroy this condition, and, though I am not warranted in saying that no kind of consciousness can exist, I am warranted in saying that such consciousness could not be *mine.* That a being now subject to the law of succession should be identical with one hereafter not so subject, implies a self-contradiction; for it implies a consciousness of the relation of present to past, and the absence of time, the basis of that relation. Succession in time is thus manifested as a constituent element of my personal existence, without which I could not be conscious of that existence; and, as consciousness is in this case reality, without which *I* could not exist. Again, consciousness in its human manifestation implies an active as well as a passive element;—a power of attending to the successive states of consciousness, as well as a succession in those states themselves. Attention appears to be necessary, not merely to the remembrance, but even to the existence of various states of consciousness as such;—indeed, attention is but consciousness in operation upon some definite object.[4] But in attention we remark, obscurely, indeed, but certainly, the presence, in a more or less obtrusive form, of the power of volition. It is impossible, indeed, to estimate by analysis the exact amount of will, in the strict sense of the term, that is implied in the ordinary cognition of objects; the frequency of the act having obliterated the distinctive marks of its several elements, before we are capable of reflecting upon them; but its presence as a constituent element is not the less surely implied, though it requires some research to disengage it. It is not going too far to say that, without the conscious exercise of volition, the distinction between the permanent subject and its transitory modes, between *myself* and *my affections,* could never have arisen in the human mind; and the consciousness of that distinction is even now observed to vary with the fact which gives rise to it, to become more or less vivid in proportion as the consciousness of voluntary action is more or less obvious. *I* am emphatically and prominently present to my own consciousness in the exercise of choice: those acts are peculiarly *mine,* which are consciously imputable to me as their cause, and for which I feel myself responsible.[5] Volition is not, indeed, the whole of personality, but it is one necessary element of it;—the consciousness of the one rising and falling with the consciousness of the other; both more or less vividly manifested, as is the case with all consciousness, according to the less or greater familiarity of particular instances; but never wholly obliterated in any;—capable at any moment of being detected by analysis, and incapable of being annihilated by any effort of thought. That a conscious being can, under no possible conditions, be a merely passive link in the chain of causation, is more than I can venture to assert; but this much I know, that such consciousness could not possibly be *my* consciousness;—that *I* could not become such a being, retaining my present personality unimpaired; but that I must be destroyed, and a distinct being substituted in my place. The freedom of the will is so far from being, as it is generally considered, a controvertible question of philosophy, that it is the fundamental postulate, without which all action and all speculation, philosophy in all its branches, and human consciousness itself, would be impossible.

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[1] "For aught I know," says Coleridge, "the thinking spirit within me may be *substantially* one with the principle of life and of vital operation. For aught *I* know, it may be employed as a secondary agent in the marvellous organization and organic movements of my body. But, surely, it would be strange language to say, that *I* construct my *heart!* or that *I* propel the finer influences through my *nerves!* or that *I* compress my brain, and draw the curtains of sleep round my own eyes!" (*Biographia Literaria*, vol. ii., p. 158, ed. 1847.)

[2] See Plato, *Theætetus*, p. 152–160; Arist. *Metaph.* i. 6, xii. 4.

[3] Professor George Wilson, in the *Edinburgh Essays*, p. 313.

[4] See *ante*, p. 575

[5] See on this point, Kant, *Religion innerhalb der Grenzen der blossen Vernunft*, part i., sect. 1.

The task, then, of the metaphysician, in this branch of his science, is to unravel and solve the difficulties which accompany the conception of personality in its twofold character,—that of existence in time, and that of free agency. The fact itself is in both cases equally indubitable: it is as certain, from the testimony of consciousness, that we are free agents, as that our ideas occur in succession, one after another. We are not called upon to account for this;—which would be to account for our own existence; every attempt at which must manifestly assume the very fact which it professes to call in question;—but, assuming this as the basis of consciousness, and, in consciousness, of personal existence, we must endeavour to meet the objections to which it is apparently liable, and which will generally be found to arise from a misinterpretation of the testimony of consciousness itself. For instance, it has been asked, how can a real thing exist in time; and, if it does so, how can we be conscious of its existence? The earlier phases of its being have passed by, and exist no more; the future exist not yet; the present is perishing as we contemplate it: How can these several phenomena make one thing? and, if they could, how can we be conscious of it? To know that my past self is identical with my present, I must compare them together: this is impossible, as they cannot be made to exist together. Nay, even to compare the thought of one with the thought of the other, I must contemplate them successively; and thus each vanishes as the other presents itself.[1] The answer to this objection may be furnished by a more accurate analysis of the idea of time itself. The consciousness of time does not simply imply succession: it implies a permanent subject under successive modifications. The object of consciousness can only be presented as successive, on the condition that the subject is presented as continuous. It is only when I become an object of consciousness to myself, that I become a member of a successive series; but in this case the object is not the presented self, but my representative conception of that self. *My notion of myself* may alternate in consciousness with my notions of other things; but it can do so only on condition that the *presented self*, the subject, and not the object, of consciousness, remains one and indivisible. The subject, it is true, cannot be contemplated apart from its modifications; for this would be to transform it from a subject to an object; but the two elements are not the less clearly discerned in the relation of consciousness; though they are discerned only in conjunction with each other. For this reason, the language which implies succession becomes obviously improper when applied to the subject of consciousness. I may speak, accurately enough, of my earlier and later thoughts or feelings; but I cannot, with any philosophical accuracy, speak of an earlier and later *self*, even as a merely logical distinction, for the sake of afterwards identifying the two. To identify is to connect together in thought objects of consciousness given under different conditions of space or time; as when I pronounce the man whom I met in the street to-day to be the same who called at my house yesterday. But *myself*, the subject of consciousness, is never given under these different relations at all. It is that presentation from which our original notion of numerical identity is drawn, and which cannot be subjected to later and secondary applications of the same idea. These considerations may perhaps throw some light on the vexed question of *personal identity*,—a question which can only be asked concerning the represented self, or notion made an object; and which cannot be asked at all without presupposing the presented identity of the subject.

A like answer may be made to the objections against free will, drawn from the supposed necessity of a determining antecedent in time. Consciousness, rightly interpreted, repudiates both the extreme theories;—that of an irresistible determinant, or set of determinants, and that of an arbitrary will, altogether uninfluenced by motives. Two alternative motives are manifested in consciousness as both influencing, but neither compelling; and the freedom of the will consists, not in being absolutely uninfluenced, but in the power of determinining which of the two influences shall prevail. Of a temporal antecedent necessarily determining my volitions, consciousness tells me nothing;—nay, it tells me the very reverse, that the influence of such an antecedent is not necessary. It is only when the idea of volition is excluded, and, with volition, that of choice, and, with choice, that of contingence, that the temporal antecedent is transformed into a necessary determinant.[2] But this merely negative idea of necessity, which is, in fact, only an inability to conceive contingence, is derived solely from the absence of volition, and is inapplicable where volition is present. The only positive notion which I possess of *causative power* is that of *myself determining my own volitions*. This notion presupposes the freedom of the person, and has no existence whatever if that freedom be denied. To apply this notion in support of the hypothesis of necessity, is not only to go beyond, but actually to reverse the testimony of consciousness. It is, in fact, to say that the consciousness of myself having absolute power over my own volitions is identical with the consciousness of something else having absolute power over me.

But if we are conscious that we are free, we are free in reality; for, as regards the personal self, consciousness *is* reality. In this respect, the ontology of the personal self, which stands in the place of the rational psychology of the pre-Kantian metaphysics, occupies a very different position from the ontology of the material world, which inherits the unsolved problems of rational cosmology. The latter science, in its only attainable form, is but a phenomenology of a higher order. It can distinguish between the permanent and the transitory attributes of matter relatively to consciousness; but it is compelled to admit the possible existence of a further material world of things, of which we are not conscious, and which may or may not resemble the objects of which consciousness, and, through consciousness, philosophy, takes cognisance. But, as regards *myself*, this supposition is inadmissible. I exist as a person only as I am conscious of myself; and I am conscious of myself only as I exist. The consciousness of personality is thus an ontology in the highest sense of the term, and cannot be regarded as the representation of any ulterior reality. The neglect of this distinction forms the weak point in the otherwise masterly discussions of Kant on the antinomies of pure reason. Denying the existence of an immediate consciousness of self, and holding, as all who deny this must do, that the freedom of the will is incompatible with exist-

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[1] See Herbart, *Lehrbuchzur Einleitung in die Philosophie*, sect. 120, sqq.; *Hauptpuncte der Metaphysik*, sect. 11.

[2] See *ante*, p. 601.

ence in time, he endeavoured to save liberty itself, and, through liberty, morality, by a distinction between the phenomenal self of consciousness, and a real self of which we are not conscious. The self of consciousness, he said, is a phenomenon existing in time; and, as such, is necessarily determined by antecedent phenomena. If, then, phenomena were things in themselves, freedom would be impossible. But beyond the field of consciousness there must exist a transcendental self, the ground and support of the phenomena; and to this transcendental subject, as under no conditions of time, we may legitimately attribute a power of self-determination, or free causality. To this attempted solution obvious objections may be raised. In the first place, it may be urged that our real personal existence is the existence of consciousness; and no higher guarantee of reality can be admitted. The self of consciousness is the true self: that which is beyond consciousness, if such can be supposed, is in this case the phenomenon. In the second place, we are not compelled in thought to postulate the existence of any transcendental self at all; for consciousness itself presents the permanent subject of its own phenomena. In the third place, liberty is so far from being incompatible with consciousness, that it is directly given in consciousness itself; for I am immediately conscious that the temporal antecedents of my volition exercise no coercion upon it. Kant's solution is, in fact, the very reverse of the truth:—it is the self of consciousness which is really free: the hypothesis of necessity can only be maintained by the gratuitous supposition of a law of causality beyond consciousness, by which I am determined without knowing it. Such a perversion of the truth, on the part of so profound a thinker, can only be explained as a consequence of that suicidal position maintained as a canon of psychology by the philosophers of the last century; namely, that I have no immediate consciousness of myself, but only of my successive mental states,—a position which can only be described as one among many pernicious results of that reaction of physical upon mental science which, under the abused name of inductive philosophy, was permitted to poison with its crude analogies the very fountain and source of philosophy itself. The same consciousness which tells me that I am compelled to believe in the existence of a material world when I am not directly conscious of it, tells me also that I am directly conscious of myself, and that I exist in and by that consciousness. To overlook the distinction thus clearly laid before us is to confound with each other the two poles of speculative philosophy, the subject with the object, the necessary with the contingent, the permanent with the transitory, the *ego* with the *non-ego*.

Beyond the attributes manifested by consciousness as essential to personality, the ontology of the soul has no province. It cannot assume those attributes as the basis of any further demonstration; for the principles of demonstration are inapplicable to real objects. Neither the simplicity of the soul nor its immortality can be demonstrated as a necessary truth; for they are not implied in the conception of personality, and beyond that conception we have no intuition of necessary relations. The favourite representation of the soul as a simple substance, indivisible, and therefore indestructible, is one which, except so far as it is synonymous with continuous existence in time, is either untrue or unmeaning. If interpreted to mean that the conception of personality comprehends only a single attribute, it is untrue; if intended to state that the soul is not composed of parts coadjacent in space, it is unmeaning, except on the principles of materialism. A material atom is an intelligible expression, whether the object which it denotes is conceivable as really existing or not. A mental atom is as utterly unmeaning as the opposite expression of a mind composed of atoms.[1] Immortality, again, however surely guaranteed upon other grounds, cannot be represented as a necessary attribute of personal existence. That which did not exist once, may, without any absurdity, be supposed not to exist hereafter. The power which was sufficient to create is also sufficient to destroy; and if man is destined to exist for ever, it is from no inherent immortality of his own, but solely because such is the will of his Maker. That we are designed for a future life, may indeed be inferred from the direct testimony of consciousness, in so far as it reveals the existence within us of feelings and principles which do not find their full satisfaction in this life; but this inference, however legitimate, does not fall within the province of metaphysics.

OF THE REAL IN THEOLOGY.

In treating of the third branch of ontology, that of rational theology, it is necessary to take a different course from that adopted by the majority of those metaphysicians who have attempted theological reasoning at all. In the number of these, however, we cannot include those philosophers, whose systems, however veiled under the language of theism, or even of Christianity, exhibit a conception of the Deity which virtually amounts to pantheism. A personal God cannot be identified with all existence; and an impersonal Deity, however tricked out to usurp the attributes of the Godhead, is no God at all, but a mere blind and immoveable law or destiny,[2] with less than even the divinity of a fetish, since *that* can at least be imagined as a being who may be offended or propitiated by the worshipper. But, however much we may sympathize with the purpose of those philosophers who have endeavoured to demonstrate, *à priori*, the existence and attributes of a personal God, we cannot help feeling that such demonstrations, whatever may be their apparent logical validity, carry no real conviction with them to the believer or to the unbeliever.[3] And the reason of this is not far to seek. No demonstration from conceptions can prove the real existence of the object conceived; and, till this is done, the demonstration of the attributes of a hypothetical object proves no more than the connection between certain thoughts in our own minds.[4] The actual existence of an object can never be shown by thinking about it; for imaginary objects are as capable of being represented in thought as real ones. Reality must be tested, not by thought, but by intuition: we must be able to point to certain facts of consciousness in which the object of which we are in search is actually presented before us; or, at least, which can only be accounted for on the supposition that such an object exists. But this argument from the facts of intuition is not *à priori*, but *à posteriori:* it does not commence with a general conception, in order to exhibit by analysis the subordinate conceptions comprehended in it, or to construct in imagination a corresponding object; but it starts from certain facts of experience, manifested in the outer or inner consciousness, in order to determine the nature of the object which those facts present or point out to us.

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[1] The only legitimate argument from the simplicity of the soul to its immortality is of a purely negative character. We are not authorized to say that we know the soul to be simple, and that therefore it is indestructible; but only that we do not know the soul to be compound (indeed, that the epithets *compound* and *simple*, as applied to the soul, have no meaning), and, therefore, that we cannot infer its mortality from the analogy of bodily dissolution. And this is, for the most part, the limit within which the argument is confined by one of the soberest as well as deepest of thinkers, the admirable Bishop Butler. The majority of philosophers, however, have not been so cautious in their reasoning.

[2] See Kant, *Beweisgrund zu einer Demonstration des Daseyns Gottes, Vierte Betrachtung*, sect. 3.

[3] For a criticism of some of the principal demonstrations of this kind, see Kant, *Kritik der reinen Vernunft.*, Abth. iii., B. ii., Hauptst. 3. The same grounds of objection are also applicable to other reasonings of this kind. Compare Waterland's *Dissertation on the Argument* à priori *for a First Cause.*

[4] See *ante*, p.602.

We must therefore begin our inquiry by asking, What are the facts of consciousness which appear directly to indicate the existence of a spiritual being superior to ourselves? Two of the intuitions of the internal consciousness appear especially to possess this character:—the *feeling of dependence*, and the *sense of moral obligation.* To these must be added, as an indirect and collateral witness, the *consciousness of limitation*, which, by suggesting, though not immediately presenting, the unlimited as its correlative, serves in some degree to interpret and connect the other two. The argument from causation, though holding an important place among the evidences of natural religion, can hardly be placed among those direct indications of consciousness which come within the legitimate province of metaphysics. We are immediately conscious, indeed, of the necessity of supposing a phenomenal antecedent to every event; but we are not immediately conscious of a necessity of conceiving that the series of phenomena is limited or unlimited. Nay, rather, we are conscious of two counter inabilities, which hinder us from conceiving either an absolutely first cause, or an absolutely unlimited series of causes and effects.[1] We have thus two contradictory hypotheses, one of which must be believed, though neither can be comprehended; and the evidence of reason being thus neutralized, we are bound to adopt that alternative which is most in harmony with the remaining testimony of consciousness. But, in so doing, we obey a moral, not an intellectual obligation; and our conviction, as far as the argument from causation alone is concerned, is not that of reason, but that of faith. The conclusion from the evidences of design in the works of creation, which is but a special form of that from causation, is likewise not an immediate suggestion of consciousness, but the gradual product of experience and comparison, arguing by analogy from what we have learned concerning the works of man to what we may infer concerning the works of God. Such arguments have great value in their own place, as illustrative of, and auxiliary to, the convictions forced upon us by our religious and moral instincts; but they are based upon reflection, not upon intuition; and, though they may serve to enlarge our conception of the Deity when once formed, they do not explain its origin and formation.

The province of the metaphysical theologian is confined to those evidences which belong to the direct testimony of the intuitive consciousness, as manifested in the feelings of dependence and moral obligation. The feeling of dependence is something very different from the mere recognition of the relation of subject to object in consciousness, and of the consequent limitation of the one by the other.[2] It is a feeling that our welfare and destination are in the hands of a superior Power; not of an inexorable fate or immutable law, but of a Being having at least so far the attributes of personality that He can show favour or severity towards those dependent upon him, and can be regarded by them with the feelings of hope and fear and reverence and gratitude, and be addressed in the words of prayer and praise. It is a feeling similar in kind, though higher in degree, to that which is awakened in the mind of the child by his relation to his parent, who is first manifested to his mind as the giver of such things as are needful, and to whom the first language he addresses is that of entreaty. With the first development of consciousness, there grows up, as a part of it, the innate feeling that our life, natural and spiritual, is not in our own power to prolong or to sustain; that there is One above us on whom we are dependent, whose existence we learn, and whose presence we realize, by the sure instinct of prayer. That this feeling is natural to us, is manifested by the universal practice of mankind;—every nation, however degraded may be its form of religion, having some notion of a superior being, and some method of propitiating his favour. We have thus, in the sense of dependence, the psychological foundation of one great element of religion—the fear of God.

But the mere consciousness of dependence does not in itself exhibit the character of the Being on whom we depend. It is as consistent with superstition as with true religion—with the belief in a malevolent as in a benevolent deity; it is as much, if not more, called into exercise by the painful and terrible aspects of nature as by the pleasing and encouraging. It indicates the power of God, but not necessarily his goodness. This deficiency, however, is supplied by the other psychological element of religion, the consciousness of moral obligation. It is impossible to maintain, as Kant has attempted to do,[3] the theory of an absolute autonomy of the will; that is to say, of an obligatory law resting on no basis but its own imperative character. The will, or practical reason, with its law of immutable obligation, is in itself a fact of the human constitution, and it is no more. Kant's fiction of an absolute law, binding upon all rational beings whatever, has only an apparent universality; because we can only conceive other rational beings by identifying their constitution with our own, and making human reason the measure and representative of reason in general. Why, then, has one part of my constitution, as such, an imperative authority over the remainder? What right has one part of the human consciousness to represent itself as duty, and another merely as inclination? There is but one answer possible. The moral reason, or will, or conscience—call it by what name we please—of man, can have no authority, save as implanted in him by some higher spiritual being, as a law emanating from a lawgiver. Man can be a law unto himself only on the supposition that he reflects in himself the law of God. If he is absolutely a law unto himself, his duty and his pleasure are undistinguishable from each other; for he is subject to no one, and accountable to no one. Duty itself becomes, in this case, only a higher kind of pleasure—a balance between the present and the future, between the smaller and the larger gratification. We are thus compelled, by the consciousness of moral obligation, to postulate a moral Deity, and to regard the absolute standard of right and wrong as constituted by the moral nature of that Deity.[1] The conception of this standard in the human mind may indeed be faint and fluctuating, and must be imperfect; it may vary with the intellectual and moral culture of the nation or the individual; and in its highest human representation it must fall far short of the reality. But it is present in all mankind, as a basis of moral obligation and an inducement to moral progress; it is present in the universal consciousness of sin—in the conviction that we are offenders against God. However degrading may be the practices into which men have fallen, under systems of false religion, it may be safely asserted that no man, and no nation of men, ever consciously deified vice as such. The voluptuous deities of the pagan mythology were deified as regards their enjoyments, not as regards their vices: their acts were contemplated as divine, not because they were breaches of morality, but because the worshipper falsely conceived them to be ingredients of happiness. The god of a nation of savage warriors may delight in revenge and bloodshed; but the supposed divinity of his acts does not consist in their cruelty: they are attributed to him because their infliction is an evidence of superiority; perhaps, also, because their endurance is a test of heroism. Even the worship of an evil principle is a worship of power, not of vice. He causes vice in man, but he is not himself vicious; for he transgresses no higher obligation of his own nature; and, even thus, he is not, in the proper sense of the term, God; for his worship implies no obligation to obey. The Deity, however falsely conceived, still represents a moral standard in the minds of his worshippers: the idea of the perfect goodness of God, as implied in the imperfect goodness of man, may be corrupted and degraded, but is never wholly extinguished. The consciousness of right and wrong, of duty and disobedience, even in its most perverted form, involves the consciousness of a being to whom duty and obedience are due; whose nature, however imperfectly represented, is necessarily conceived as moral; and whose commands, emanating from that nature, are manifested in the authority which they communicate to the moral principle in man.

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[1] The counter arguments on either side are exhibited by Kant, in his first antinomy of pure reason. The same conclusion, however, is evident, without argument, from the direct testimony of consciousness. For to conceive an absolutely first member of the causal series is to conceive a beginning of all time, and thus to be conscious of a relation of time to an object out of time, and therefore out of consciousness; and to conceive an infinite series of causes and effects, we must carry our thought through an infinite succession of objects,—a process which would require an infinite time to accomplish it.

[2] In consequence of not distinguishing between these two, Schleiermacher (*Christliche Glaube*, sect. 4) has fallen into the error of representing our relation to the world as a feeling of partial dependence, and our relation to the Deity as one of absolute dependence. Thus represented, God can no longer be conceived as a person, but is nothing more than the world magnified to infinity; and the feeling of absolute dependence becomes the annihilation of our personality in the being of the universe. Of this feeling, the intellectual exponent is pantheism.

[3] See *Metaphysik der Sitten* (Abschn. ii., pp. 61, 71, ed. Rosenkranz). Thus refusing to acknowledge an intuition of God as a moral lawgiver, Kant is compelled to rest the evidence of the existence of the Deity on an assumed necessity of rewarding men according to their deserts, a necessity which implies an all-wise judge who can estimate merit in every degree. For an able criticism of Kant's theory, see Müller, *On the Christian Doctrine of Sin* (vol. i., p. 73, of the English translation).

But though we have thus the direct testimony of consciousness to the existence of a superior being, on whom our life and welfare depend, and from whom our moral obligations emanate, the being thus manifested does not yet realize the full idea of the Deity. For neither in dependence nor in moral obligation can we have an immediate intuition of the Infinite. The dependent is not absorbed in that on which it depends: the consciousness of our personal existence is not annihilated when we feel its relation to a higher power. Self and not-self still divide the universe of existence between them; and neither can be regarded as exhausting it.[2] But that which coexists with the finite cannot be itself conceived as infinite; otherwise the infinite and the finite together must be conceived as greater than the infinite. Nor yet can the finite be conceived as merged in the infinite; for this would be to conceive myself as existing and not existing at the same time. In like manner, it is impossible to conceive an infinite moral nature; for each moral attribute, as coexisting with others, limits and is limited by the rest; and the very conception of morality implies law, and law is itself a limitation. Yet, on the other hand, we cannot escape from the conviction that the infinite does in some manner exist, and exists, though we know not how, along with the finite; and though we can form no positive conception of its nature, we cannot regard the limits of our conception as the limits of all possible existence. We know that, unless we admit the existence of the infinite, the existence of the finite is inexplicable and self-contradictory; and yet we know that the conception of the infinite itself appears to involve contradictions not less inexplicable. In this impotence of reason we are compelled to take refuge in faith, and to believe that an infinite being exists, though we know not how, and that he is the same with that Being who is represented in consciousness as our sustainer and our lawgiver. For the contradictions involved in the denial of the infinite are positive, and definitely self-destructive; as we directly conceive the universe as limited, and yet as limited by nothing beyond itself; whereas the contradictions involved in the assumption that the infinite exists are merely negative, and might be soluble in a higher state of intelligence; as they arise merely from the impotence of thought, striving to reduce under the conditions of conceivability that which is beyond its grasp. Thus they are not contradictions manifested in the infinite itself, but only limitations in our power of comprehension. We are compelled, therefore, by reason, as well as by faith, to acknowledge that the infinite must exist; though how it exists, reason strives in vain to fathom, and faith rests content with the duty of believing what we cannot comprehend.

Hence we are compelled to admit that theology as well as cosmology, viewed as a branch of philosophy, is not a true ontology, but only a higher kind of phenomenology. We believe in the existence of an infinite God; and we know also that we cannot conceive Him *as* infinite. Our highest conception of the Deity is still bounded by the conditions which bound all human thinking, and therefore cannot represent the Deity as He is, but only as He appears to us. Such a representation, though sufficient for all the practical purposes of religion, is unable to satisfy in full the demands of a philosophical curiosity. But a sounder and more sober philosophy will tell us why those demands cannot be satisfied;—why the highest problems of speculative theology must and ought to be abandoned as insoluble. It tells us that our whole consciousness is relative, and therefore cannot comprehend the absolute; that our whole consciousness is limited, and therefore cannot comprehend the infinite. It tells us that a comprehended infinite could be no infinite at all; for comprehension itself is a limitation; and the unlimited must necessarily be the incomprehensible. To know God as He is, man must himself *be* God. The pantheist accepts this position, and identifies the Divine mind with the universal consciousness of mankind. The theist accepts it also, and is content to worship where he cannot understand.

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[1] The theory which places the standard of morality in the *Divine nature* must not be confounded with that which places it in the arbitrary *will* of God. On the latter, see the remarks of Sir James Mackintosh, *Second Dissertation, ante*, vol. i., p. 312; and of Müller, *Christian Doctrine of Sin*, vol. i., p. 95. God did not create morality by his will: it is inherent in his nature, and coeternal with Himself; nor can He be conceived as capable of reversing it. But God did in one sense create human morality, when He created the moral constitution of man, and placed him in certain circumstances, such as those of mortality, of property, of sexual relation, &c., by which the eternal principles of morality are modified during this present life. On the foundation of morality in the nature of God, see Cudworth, *Treatise Concerning Eternal and Immutable Morality*, b. i., ch. iii.; b. iv., ch. iv. v. vi.

[2] Schleiermacher (*Christliche Glaube*, sect. 4, 5) maintains a different view. He resolves the religious consciousness into a feeling of *absolute dependence*, in which the consciousness of our own individuality and activity in relation to a distinct object of consciousness disappears in that of a passive relation to the infinite God. In this view he is followed by Mr Morell, who says that man, "in the presence of that which is self-existent, infinite, and eternal, may feel the sense of freedom utterly pass away, and become absorbed in the sense of absolute dependence." (*Philosophy of Religion*, p. 75.) Without dwelling on the difficulties and apparent contradictions involved in the notion of an absolute dependence which is, at the same time, a relative consciousness, this theory appears to be open to one fatal objection; namely, that it makes our moral and religious consciousness subversive of each other, and reduces us to the dilemma that either our faith or our practice must be founded on a delusion. The actual relation of man to God is the same, in whatever degree man may be conscious of it. If man's dependence upon God is really not destructive of his personal freedom, the religious consciousness, in denying that freedom, is a false consciousness. If, on the contrary, man is in reality passively dependent upon God, the consciousness of moral responsibility, which bears witness to his free agency, is a lying witness. When Schleiermacher assumes the existence of three degrees of consciosuness,—1. That of the infant, in which there is no conscious distinction of the subject from its object; 2. The middle state of distinct relation between self and not-self; and 3. The highest or religious consciousness, in which the relation again disappears,—he overlooks the fact that the second and third are not successive stages in the mental development, but must alternate with each other during a man's whole life; the one presiding over his moral duties, and the other over his religious feelings. On what ground is one of these states to be regarded as higher than the other, except in so far as it more truly reveals to us our actual state in the sight of God, as free or absolutely dependent? And as this state must be always the same, whether we are conscious of it or not, it follows, that in proportion as one of these states reveals to us the truth, the other must be regarded as testifying to a falsehood.

If this limitation of philosophical theology be admitted, the ground of many a controversy, and the root of many a heresy, is cut from under it at the very commencement of inquiry. In acknowledging the existence, and at the same time the incomprehensibility, of the infinite, we at once confess that we have sufficient grounds for belief, but not for theory. If we have no conception of the infinite attributes of God as such, we may not so interpret those attributes as to place them in antagonism, either to the direct testimony of consciousness, or to the plain language of Scripture; nor yet, on the other hand, can we distinctly show their compatibility with either, though we are bound to believe it. How, for example, can we reconcile man's free-will with God's foreknowledge? Rather, why should we attempt to do so, when in the attempt we must needs substitute our limited conception of the Divine nature for that nature as it is. We know not how an infinite intelligence contemplates succession in time: we know not whether his consciousness is subject to the law of succession at all. Eternity, in relation to the Divine mind, may be, as the schoolmen called it, a *nunc stans*, in which there is neither past, nor present, nor future. Foreknowledge may be merely a means of accommodating the representation of Divine omniscience to human faculties. To speculate in any direction,—to adopt a theory of *scientia media* on the one hand, or of absolute predestination on the other,—is to deify our own ignorance; to make the human conception the measure of the Divine reality. Why, again, cannot we conceive infinite power as undoing that which is already done. If the sun has risen this morning, why can we not conceive that even Omnipotence can now cause that it shall not have risen? Simply, because we cannot conceive infinite power at all:—the limitation is not of omnipotence in itself, but of all power as the object of human thought. How, again, can we reconcile the exercise of two Divine attributes with each other? How can infinite mercy pardon every sin, and yet infinite justice exact the utmost penalty? How can we tell, when we can conceive justice and mercy only in their finite forms, as they are capable of existing in human consciousness? It is obvious how the same principles may be applied to controversies concerning those deeper mysteries of the Christian faith which rest on the evidence of revelation only. But into this sacred ground it would be foreign to our present argument to enter.

OF THE REAL IN MORALITY.

The ontology of morals is subject to the same limitations with that of religion. If the standard of perfect and immutable morality is to be found only in the eternal nature of God, it follows that those conditions which prevent man from attaining to a knowledge of the infinite as such, must also prevent him from attaining to more than a relative and phenomenal conception of morality. And, in truth, man's moral, like his religious consciousness, will vary according to his state of mental and moral culture: he may have higher or lower ideas of duty, as he may have higher or lower ideas of God. But it does not, therefore, follow, as was maintained by the sophists of old, that each man is the measure of all things to himself, and that morality is nothing more than the law which any man or nation chooses to enact for a certain time within a certain sphere.[1] The very expressions, a *higher* and a *lower* standard, imply that there are degrees of right and wrong, even in relative and phenomenal morality;—that one human conception of duty may be more perfect than another, even if none can attain to absolute perfection. There is such a thing as an enlightened and an unenlightened conscience; though no man may presume to say that his own conscience has attained to the greatest amount of enlightenment of which even human nature is capable. It is a mark of the progressive character of natural morality and religion, that no new advance in knowledge contradicts the *principles* which have previously been acknowledged by the conscience; however much it may modify the particular acts by which those principles are to be carried out. To be zealous in God's service is a principle of religious duty common to Saul the persecutor and to Paul the apostle; though its result in action is at one time to destroy the faith, and at another to preach it. And it is a mark of the same character, that each fresh advance in moral and religious knowledge carries with it the immediate evidence of its own superiority, and takes its place in the mind, not as a question to be supported by argument, but as an axiom to be intuitively admitted. Each principle of this kind recommends itself to the minds of all who are capable of reflecting upon it, as true and irreversible as far as it goes; though it may represent but a limited portion of the truth, and be hereafter merged in some higher and more comprehensive formula. The principles, for example, that virtue, relatively to the human constitution, consists in observing a mean between two extremes, or in promoting the good of others, or in a reasonable self-love, all represent views containing a portion of truth; though none can be considered as exhausting the whole truth. While human nature is complex in itself, and susceptible of various relations and various duties arising out of those relations, it is not to be expected that all human virtue should be reducible to a single attribute, or capable of expression in a single formula. Yet its general character is not therefore doubtful, because it admits of being viewed in various special relations. Two men who differ in their definition of virtue will yet generally be agreed as to who is the virtuous man. "Let me die the death of the righteous, and let my last end be like his," expresses the conviction of one who, though far from righteous himself, was yet compelled to acknowledge the existence of a higher human standard than his own rule of conduct.[1] "As much as it has been disputed," says Bishop Butler, "wherein virtue consists, or whatever ground for doubt there may be about particulars; yet, in general, there is in reality an universally acknowledged standard of it. It is that which all ages and all countries have made profession of in public: it is that which every man you meet puts on the show of: it is that which the primary and fundamental laws of all civil constitutions over the face of the earth make it their business and endeavour to enforce the practice of upon mankind:—namely, justice, veracity, and regard to common good."[2]

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[1] So far from it, that the above ground is constantly taken by the antagonists of the sophistical doctrine, for the express purpose of refuting it. Thus Plato, in the Dialogue especially devoted to the refutation of the dogma of Protagoras, that "man is the measure of all things," asserts that some portion of evil must needs exist in our mortal nature, and that we must endeavour to escape from it by an imitation, according to our power, of the Divine justice and holiness. (*Theætetus*, p. 176.) And Aristotle, after stating, as opposed to his own view, the sophistical position that all justice is conventional and variable, remarks,—*καίτοι παρά γε τοῖς θεοῖς ἴσως οὐδαμῶς.* (*Eth. Nic.* v. 7.) Even the comic poet, in his Dialogue between the Unjust and the Just Discourse, representing respectively the sophists and their antagonists, puts into the mouth of the latter the same argument:—

ΑΔ. *οὐδὲ γὰρ εἶναι πάνυ φημὶ δίκην,*
ΔΙ. *οὐκ εἶναι φῄς;* ΑΔ. *φέρε γάρ, ποῦ 'στιν;*
ΔΙ. *παρὰ τοῖσι θεοῖς.* (Aristoph. *Nubes*, 902.)

Nevertheless, there is an useful lesson to be drawn from the frequent fluctuations of men's moral theories, as well as from the general agreement of their practical confessions. It is not unusual for philosophers to reason as if they were possessed of an absolute, and not merely of a relative standard of morals;—as if they had attained to the conception of eternal morality, as it exists in the nature of God, instead of to that temporary modification of it which is adapted to a particular state of the constitution, and stage of the progress, of man. The works in which Kant and Fichte have attempted to construct an *à priori* criticism of revelation, upon moral grounds, are remarkable instances of this departure from the limits of all sound philosophy.[3] Both assume that the sole purpose of revelation must be to teach men morality; and both assume that the morality thus taught must be identical to the minutest particular with the system attained by human philosophy;—which last is supposed to be absolutely infallible. Hence Kant maintains that the revealed commands of God have no religious value, except in so far as they are approved by the moral reason of man; and Fichte lays down, among the criteria of a possibly true revelation, that it must contain no intimation of future reward or punishment, and must enjoin no moral rules which cannot be deduced from the principles of the practical reason. Whereas, in truth, the principles of the practical reason are susceptible of additional enlightenment with every stage of man's progress in this life (and it may be also with every stage of his progress in the life to come), and revelation, in two sentences, has conveyed to us a principle of human morals, which the philosophy of ages had toiled after in vain, and which the philosophy of a later day has been content to borrow without acknowledgment, and to pervert in attempting to improve:—"Thou shalt love the Lord thy God with all thy heart, and with all thy soul, and with all thy strength, and with all thy mind; and thy neighbour as thyself."[4]

OF THE REAL IN THE PHILOSOPHY OF TASTE.

With the ontology of morals is not unfrequently associated that of taste. The good and the beautiful were in the Greek language often expressed by the same word; and are by many regarded as alike expressing absolute and immutable principles, equally independent of human opinion, and equally objects of philosophical inquiry.[5] But, in truth, the object of the so-called philosophy of æsthetics appears, even in its highest form, to have far less of an absolute and immutable character than belongs to the objects of metaphysical inquiry, even within the limits to which they have been confined in the preceding pages. The beauty of an object appears to depend, not so much on the character of the object itself, as on the feeling of pleasure which it excites in the spectator; and this, again, on the accidents of his present constitution.[6] This appears to be the case even with the moral beauty of an action, when that quality is viewed apart from the other ingredients of its moral character. The consciousness that a certain action is morally pleasing to me is not necessarily connected with that of its moral rectitude; though the two have frequently been confounded together in the various theories concerning the moral sense.[7] But it is easy to conceive that moral obligation might remain undiminished, even if no gratification were derivable from the observance of it; while, on the contrary, it seems impossible to conceive the existence of an obligation to be pleased, apart from the apprehension of the moral character of the act. The beauty of sensible objects appears to exhibit still more fully the marks of a merely phenomenal and relative character. A slight change in the shape and refractive power of the eye would alter all our perceptions of the form and colour of objects, and, with them, the impressions of beauty and deformity derived from this source. And if the senses themselves are confined to the apprehension of phenomena, how can the beauty of the objects of sense lay claim to a higher character? Can we then assert that sensible beauty is a reflection and imitation of ideal beauty, even in the same manner and degree in which our perceptions of moral duty aim at and imply a divine standard of right and wrong? Even the fluctuation in the opinions of various individuals and nations, though far from being a decisive criterion in any case, appears to be acknowledged by the general sense of mankind to be a test more conclusive in questions of taste than in those of truth or rectitude. The very name *taste* seems to imply something subjective, and, to a considerable extent, arbitrary. The maxim, "*De gustibus non disputandum est*," may be the exaggerated expression of a popular conviction; but, at any rate, it carries no such shock to the natural feelings of mankind, as does the sophistical assertion that the distinctions between truth and falsehood, virtue and vice, are based on convention, and not on nature. Nor is it difficult to detect the foundation of truth which underlies the exaggeration. The maxim is true, in so far as it virtually asserts that beauty is subjective, not objective; an affection of the person who is conscious of it, existing only in and by that consciousness, not a permanent quality, existing in things, and capable of being expressed by a general notion.[8] But it is exaggerated, in so far as it apparently denies the existence of a common sense of beauty, among men of cultivated minds, by virtue of which similar affections will be produced in different minds by the same object.[9] But this admission, while it saves the standard of taste from the charge of arbitrariness and instability, at the same time removes the philosophy of taste from the province of ontology, and limits it to a psychological investigation of those relations between the imagination and the understanding which give rise to the consciousness of beauty in an object actually present.[1]

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[1] See Bishop Butler's *Sermon on the Character of Balaam*.

[2] *Dissertation on the Nature of Virtue.*

[3] See Kant's *Religion innerhalb der Grenzen der blossen Vernunft*, and Fichte's *Versuch einer Kritik aller Offenbarung*.

[4] See Kant's criticism and attempted explanation of these precepts, *Kritik der praktischen Vernunft*, B. i. Hauptst. iii. (p. 209, ed. Rosenkranz).

[5] See especially M. Cousin's Lectures, *Du Vrai, du Beau, et du Bien*, where absolute beauty is referred to the same Divine standard with absolute goodness and absolute truth: and so Hutcheson entitles his treatise *An Inquiry into the Original of our Ideas of Beauty and Virtue*.

[6] See Kant, *Kritik der Urtheilskraft*, sects. 1, 6, 15. (*Werke*, iv., pp. 46, 56, 76.) The sublime, as well as the beautiful, is admitted by Kant to be not a quality of things, but a feeling of our superiority over nature. (*Ibid.*, sect. 28, p. 122.)

[7] See *ante*, p. 580.

[8] See Kant, *Kritik der Urtheilskraft*, sect. 17. (*Werke* iv., p. 81.)

[9] See Kant, *Kritik der Urtheilskraft*, sects. 6, 22. Kant resolves the feeling of beauty into an indefinite consciousness of *fitness with reference to an end* (Zweckmässigkeit), but without the representation of any definite end. He admits, however, that this consciousness is merely subjective, and that there can be no objective rule, capable of determining beauty by conceptions.

CONCLUSION.

We have thus indicated, rather than discussed, some of the manifold aspects of the great fundamental problem, which, various in its external forms, but one in its real import, has stimulated the researches of thoughtful men in all ages, under the names, used for the most part synonymously, of First Philosophy, Ontology, or Metaphysics:—the problem, namely, to distinguish *that which is* from *that which seems to be.* Whether we look to its earliest definite statement, in the dogma of Parmenides, that being is one and unchangeable, and that variety exists only in the fancy of men; or to the boast of Zeno, that he would explain all things if there were only given to him the one;—whether we examine Plato's conception of the science of dialectic, as that which contemplates real existence by the aid of the pure intellect, illuminated by the brightness emanating from the essential form of good; or ask the question which the same philosopher describes as embracing at once the deepest mysteries of philosophy and the pettiest quibbles of sophistry, How can the one be many, or the many one;—whether we adopt Aristotle's definition of the first philosophy, as the science which contemplates being as being, and the attributes which belong to it as such; or, with Descartes, assume the fact of our own personal existence, manifested in consciousness, as the one primary and indubitable truth;—whether, with Leibnitz, we regard the sensible world as composed of an aggregate of unextended monads or metaphysical points; or, with Kant, divide objects into noumena and phenomena, things as they are in themselves and things as they are related to human faculties; or, with Fichte, postulate the existence of an absolute self, implied by, though not given in consciousness; or, with Schelling, attempt by intellectual intuition to reach the point of indifference in which the relations of subject and object are merged in the identity of both; or, with Hegel, found a philosophy on the hypothesis of an absolute thought, identical with absolute being, and susceptible of development into the various modes of personal and impersonal finite existence; or, with Herbart, find a common object of all metaphysical inquiries in the solution of the contradictions which present themselves in experience;—in all these, and other different statements, we recognise only verbal varieties of one and the same fundamental distinction;—a distinction which, however perverted in artificial systems, must have a natural origin in the human mind; which must be given in one mode of consciousness, or else it could not have been invented in any.

We have endeavoured to ascertain the primary and presentative fact of consciousness in which this distinction is given,—a fact upon which all the secondary and representative varieties of it must be based; and thus to fix the limits within which a science of real being is possible, and beyond which it cannot be carried. This fact seems to be discoverable in the relation between a permanent self and its successive modifications, which forms the condition of all human consciousness. If this be admitted, ontology, in the highest sense of the term, becomes identified with psychology; and the future task of the metaphysician will consist in exhibiting the conditions involved in the idea of personal existence, and solving the difficulties to which that idea appears to give rise. To attempt to accomplish this task in detail would require a far greater space, and a more minute examination, than is possible within the reasonable limits of an article like the present. We must content ourselves with having pointed out the fact that such problems exist, and stated the reasons for believing that they are not to be abandoned as insoluble.

Beyond the range of personal existence we have no positive conception of real being, save in the form of those more permanent phenomena which constitute our general conceptions of certain objects, as distinguished from the transitory phenomena with which those conceptions are at certain times associated. Here ontology is but a higher kind of phenomenology: its object is not a thing in itself, but a thing as we are compelled to conceive it; and to attempt to give to this branch of philosophy a more absolute character is to substitute negative ideas for positive,—to desert thoughts, and to take refuge in words which have no real meaning, save in relation to a different mode of consciousness. We do not, therefore, attempt to solve the higher problems of cosmology and theology, nor even to indicate the conditions under which they might be solved. But we have attempted to show why they are insoluble, and what is the origin of that delusion which has led men in various ages to fancy their solution possible, and to devise systems for accomplishing it. The failures of great minds are often not less instructive than their successes; and the time that is spent in wandering among the mazes of metaphysical speculation will not be wholly lost, if it teach us that knowledge which it is the end and aim of all sound philosophy to inculcate,—the knowledge of ourselves and of our faculties; of what we may and what we may not hope to accomplish; of the laws and limits of reason; and, by consequence, of the just claims of faith. (H. L. M.)

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[1] See Kant, *Kritik der Urtheilskraft*, sect. 34.

Metapontum
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Metastasio.

METAPONTUM, or METAPONTIUM, a city of Magna Græcia, was situated on the Tarentine Gulf, 14 miles from Heraclea, and 24 from Tarentum. It was colonized by Achæans about the beginning of the seventh century B.C.; but some ascribe to it a much earlier origin. In the early period of its history Metapontum was in all probability in alliance with Sybaris and Crotona, cities likewise of Achæan origin; and it was imbued to a considerable extent with the opinions and doctrines of Pythagoras, who retired to this city and spent there the last days of his life. His tomb was still to be seen there in the time of Cicero. The Metapontines assisted the Athenians in their Sicilian expedition (415 B.C.), being at that time in a flourishing condition of wealth and prosperity. They embraced the side of Pyrrhus in his war with the Romans, and after its conclusion fell under the Roman yoke. When Hannibal invaded Italy the Metapontines, after the battle of Cannæ, were well disposed to him; but, on account of a garrison of Romans, were unable openly to desert to him till 212 B.C., when the city was occupied by a Carthaginian garrison. When Hannibal was compelled to leave Italy he removed, along with his own troops, the inhabitants of Metapontum; and from that time the city disappears from history. Some remains of it are still to be seen.

METASTASIO, PIETRO, whose original name was *Pietro Trapassi*, was born in Rome, 3d January 1698. His father, Felice Trapassi, a native of Assisi, had been forced by the poverty of his family to enter the Corsican regiment of the pope, had subsequently married, supported himself by copying legal documents, and saved money enough to open a shop in Rome, in partnership with a friend, for the sale of oil, meal, and other things of the kind. His mother was Francesca Galasti of Bologna. They had two sons, the elder of whom, Leopoldo, afterwards became an advocate, and distinguished himself as a religious polemic; and two daughters. Pietro from his earliest years showed an extraordinary talent for improvisation, and was accustomed to entertain his playmates in the street with impromptu rhymes. The celebrated jurist Gravina, having accidentally heard him so engaged while passing his father's shop one day, was so much interested by his precocious talent, and by the sweetness and modesty of his manners, that he proposed to his parents to adopt and educate the boy as his own son. The proposal was accepted. Gravina, who was a Grecian and a pedant, changed his name to Metastasio, from the Greek equivalent to *trapassamento*. Intending to educate him for the bar, where he thought his powers of improvisation and eloquence might be turned to most account, he sent him to his cousin Caroprese, in Calabria, to be taught Greek and philosophy. In a letter to Mattei, the poet dwells on these youthful studies with enthusiasm. Gravina did not, however, interdict what was his own favourite employment, the reading of the ancient poets, nor the practice of improvisation; and the handsome, modest, and vivacious boy was loved and admired in Naples and Crotona by the society to which the influence of his patron admitted him. He relates in one of his letters that he was accustomed at this time to engage in poetic contests with the most distinguished *improvisatori;* but the excitement being found prejudicial to his health, Gravina caused him to break it off, and apply himself more closely to the study of the Greek poets and of the early Italian writers, and to the cultivation of a correct style. For this course of conduct Metastasio afterwards expressed his gratitude, censuring the practice of improvisation as extremely injurious to taste and labour. At the age of twelve he translated the *Iliad* of Homer in *ottava rima;* and two years later he composed the tragedy of *Giustino*, on the model of his patron's dramas,—stiff and feeble imitations of the Greek,—borrowing the plot from the *Italia Liberata* of Trissini. An edition of this tragedy is extant, printed in 1713. In a letter to Calsabigi, who superintended the Paris edition of his work in 1755, he expresses his regret that this immature production had been included. Yet it is not without beauties prophetic of the *Olimpiade*. The story is simple and affecting, and the plot is developed with much clearness. In 1714 Caroprese died, leaving Gravina his heir, who in consequence went into Calabria and rejoined his adopted son. These mingled occupations of poetical and legal study Metastasio pursued till the death of his benefactor in 1718. The blow was severely felt by the poet, who composed on the occasion an elegy entitled *La strada alla gloria*, which he recited, amid the tears of the audience, to the literary society founded by his distinguished patron. Gravina bequeathed him his Roman property, amounting to 15,000 scudi (between L.3000 and L.4000); and finding himself at the end of two years nearly penniless, he resolved to resume his legal studies. With the view of opposing a powerful barrier to his inclination, and escaping the seductions of society, he went to Naples, and placed himself under the tuition of the eminent lawyer Castagnuola, whose aversion to poetry was such that Metastasio was compelled to observe the strictest secrecy in his favourite pursuits. His genius was, however, too well known, and too highly appreciated by the refined society in which he moved, to permit him long to resist the struggles of nature, seconded by admiration and flattery. He composed an epithalamium of 100 stanzas, in *ottava rima*, on the occasion of the marriage of the Marchese Pignatelli; and on the same occasion, perhaps, his first musical drama, *Endimione*, in 1721. But the event that fixed his destiny was the following:—The birthday of the Empress Elizabeth, consort of Charles VI., occurring during her pregnancy, the viceroy wished to celebrate it with unusual splendour, and requested Metastasio to write an opera. The latter complied, exacting a promise of strict silence with regard to the author's name, and produced *Gli Orti Esperidi*, which was received with the most unusual and unbounded applause. The viceroy was so highly gratified that he presented the poet with 200 ducats. At first every one was ignorant of the author, and supposed it to be the work of some Roman poet: not even the composer, Porpora, nor the actors knew. But Marianna Bulgarelli, known as "La Romanina," from her birthplace, who had performed the part of Venus with great success and profit, succeeded in discovering him. *Gli Orti Esperidi* was published, with the name of the author, the same year at Naples. The opera of *Angelica*, also composed by Porpora, was produced on the same occasion in 1722. It is not clear whether it was before or after the production of *Angelica* that Metastasio finally determined on abandoning the legal profession. He quitted the house of Castagnuola, and went to live with La Romanina and her husband. She introduced him to Porpora, from whom he received instructions in the theory of music, and doubtless much insight into the converse adaptation. From La Romanina herself he confesses to have learned much. Mattei asserts, as from good authority, that the finest situations in his next work, *Didone Abbandonata*, written for the carnival 1724, were suggested by this accomplished actress. This opera, composed by Sarro, and produced at Naples in that year, and afterwards composed by Vinci, and produced at Rome and Venice in the following years, rapidly spread the fame of Metastasio over the peninsula as the great dramatist of the age. In 1727 La Bulgarelli took leave of the stage, of which she had been now for eighteen years an ornament, and returned to her native city, taking with her her husband and her *cicisbeo*. *Catone in Utica* was written for the Roman stage in 1728, and was Metastasio's first (if we except *Giustino*) and last attempt in regular tragedy. The reception it met with convinced him that it was impossible to harmonize the requirements of the musical drama with those of tragedy: he changed the conclusion, adapting

Metastasio.

it to the powers of his actors and the taste of his audience, and never forgot the lesson. *Catone* was composed by Vinci for Rome, and next year by Leo for Venice. *Ezio*, *Alessandro nell' Indie*, and *Semiramide* rapidly followed, extending his fame, but not much improving his circumstances. Feeling himself partially dependent on La Bulgarelli, and with no very brilliant prospects, he became despondent, when in September 1729 he received a letter from Prince Pio of Savoy, director of the court theatre in Vienna, commissioning two dramas, and inviting him thither to occupy the post of imperial poet, with an annual salary of 3000 florins. This appointment he owed to his fame, to the influence of the Princess Althan, and the generosity of Zeno, who retired on a pension. Metastasio welcomed it with eagerness. He merely requested time to complete his Roman engagements, chiefly the *Artaserse;* and having done so, he took a tender farewell of his family, and of the faithful Marianna, whom he never saw again, and repaired to Vienna in April 1730. He was received with cordiality in the house of Niccolo de Martinez, *cerimonière* of the apostolic nuncio, where he continued to reside till his death.

The dramas which he produced in the year succeeding his arrival, *Adriano in Siria* and *Demetrio*, both composed by Caldara, and performed within a few days of each other, had great success. That of *Issipile*, written in the following year, moved the emperor from his customary reserve, and procured the poet his personal congratulations. His fame increased with the operas of *Giuseppe*, *Demafoonte*, and the *Divine Olimpiade*, which successively appeared in 1733. To the plaudits of the *Olimpiade* the emperor added the more solid recompense of a treasurership in Naples, of which, however, he was in a few years bereft by the war of the succession. His life at this period may best be read in his letters to La Bulgarelli, written with great expansion and confidence. His soul was in his work: the scenes which touched his audience had first moved himself. "I send you," he writes, "a sonnet composed while I was writing a pathetic scene (it was the ninth scene of the second act of the *Olimpiade*), with which I was so much affected, that I found myself in tears." He sends her directions for the representation of *Demetrio* in Rome, asks her for suggestions and for advice, and talks of the applause he was receiving. While engaged on the *Clemenza di Tito*, February 1734, the news of Marianna's death reached him. For some time he was quite overpowered. She bequeathed him her whole fortune, amounting to 25,000 Roman scudi, which he at once made over to the widower. There cannot be much doubt as to the nature of his connection with the actress. The pious expressions he makes use of on the occasion, in a letter to a friend (Burney, vol. i., p. 109), are not sufficient to refute an inference so entirely warranted by all the facts, and by the state of society then, and unfortunately still, existing in Italy. His immediate and generous renunciation of her legacy procured him great credit. That act was one quite in harmony with the tenor of his whole life. From this time onward Metastasio's life was laborious and peaceful, little disturbed in outward appearance by the political distractions that followed the death of Charles VI. in 1740, or that of Charles VII. in 1744. On the former occasion he received excellent and honourable proposals from various courts, but he adhered to the fortunes and service of Maria Theresa, whom he had taught Italian, and who was personally attached to her tutor. During this period he produced his best works, writing only at the command of the court, and writing rapidly. He told Burney that the opera of *Achille in Sciro*, produced in 1736 on occasion of the marriage of Maria, was written in eighteen days, and that of *Ipermestra*, in 1744, in nine. The operas of *Temistocle* and *Attilio Regolo*, with the exception of the *Olimpiade* perhaps his best works, belong to this period; *Temistocle* being produced in 1738, and *Regolo* being interrupted in 1740 by the death of the sovereign.

This continual labour, and the ungenial climate of Vienna, brought on in 1745 a serious illness, which obliged him to suspend his exertions. His malady was chiefly a nervous one, and he suffered from it more or less till his death. An occasional visit to his native country would perhaps have better reconciled his constitution to the severity of the Austrian climate, of which he so often bitterly complains; but excepting an annual visit to the seat of the Princess d'Althan in Moravia, he never stirred from Vienna. His days were spent in the society of the Martinez, and of a few congenial friends. Burney, who visited him in 1772, gives an interesting account of his mode of life and his conversation (*State of Music in Germany*, &c., vol. i., p. 298 ff.); but the principal, almost the only, source of information about him during this latter period are his own delightful letters. These give a fine picture of the nobleness, generosity, and kindness of his disposition. His most intimate friend was the celebrated singer Farinelli, to whom he writes as his "twin brother" (*gemello*), and who appears to have deserved and reciprocated his affection. These letters also show how thoroughly he had studied and comprehended the requirements of the composer, and with what care and judgment he adapted his dramas to the necessities of music. The ancient poets he read assiduously. Ovid was his particular favourite, as we might guess from the frequent occurrence of Ovidian sentiments in his works. In spite of the care of Gravina, he does not appear to have ever mastered the Greek language sufficiently to enable him to appreciate their tragic writers. The analysis he has left of them proves this; and he confesses to the difficulty he had of reading the *Poetics* of Aristotle, of which he has also left an imperfect abstract. Of the Italians, his great favourite and model was Tasso, to whom he revolted at an early age from the Ariostisti, and Marino, the so-called depraver of Italian poetry, whom he always read before sitting down to work. Metastasio died in Vienna on the 12th of April 1782. A fever, caught by exposing himself on the occasion of the pope's visit, carried him off in twelve days. He was buried in the church of St Michael. He left the younger Martinez heir to his real property and a fortune of 130,000 florins, with deduction of 2000 for each of the two sisters and 3000 for each of the three brothers of the legate. He had survived all his Italian relatives.

The dramatic works of Metastasio are of the very highest excellence in their kind. Judged simply as dramas, and in front of Shakspeare, Corneille, and Racine, they will be pronounced exceedingly defective in point of characterization, motive, and probability; but regarded as compositions to be set to music, they are unequalled. What are excellences and necessities in the spoken drama, become, when transferred to the sung drama, difficulties in the way of the composer and the audience. On the other hand, the improbabilities of incident and situation which would shock an audience in the spoken drama, tend to heighten the pleasure derived from music; the music itself, the greatest improbability, being already conceded. In estimating his powers, all those points in which Metastasio falls infinitely short of the real dramatists must be taken into account; but in estimating the value of his works, it matters little whether he was deficient in true dramatic genius, or voluntarily renounced its exercise. One thing only is to be regretted, that Metastasio did not exercise more judgment in the choice of his subjects: we may grant all his sentiments, incidents, and motive, but not that they should be introduced into history, or attached to great historical characters. Cæsar, Amilcar, and Regulus, are too distinctly marked and too incongruous with the subject to be made the heroes of a love story. With such a choice, besides, the defects of

Metellus.

historical and local colouring become quite too glaring. Metastasio, in his letter of thanks to Zeno, says that the latter was his master and model. Apostolo Zeno rescued the Italian opera from the debasement into which it had sunk, and which is so admirably described in Marcello's *Teatro alla Moda*. He is a poet of high ability, if not of first-rate genius. He as much surpasses his pupil in force of characterization, simplicity and strength of expression, and accuracy of historical colouring, as he falls short of him in sweetness, delicate clearness, and musical adaptability. It is in these that Metastasio's great merit consists. His songs are already music. "He exerted himself to fulfil every demand of music. He shortened the recitative; he enlivened the dialogue. And as his mother tongue, now in the highest degree refined, was quite at his command, he made of the Italian rhythm a syllable music, which is single in its kind." (Bouterwek, *Gesch.* ii., p. 493.) The Italian critics have almost deified Metastasio. In respect of style, perhaps, they are the only proper judges; but it is impossible to agree with all that Andres, Arteaga, and Baretti have uttered in his praise. The sweetness, harmony, and lyrical rounding and finish of many of Metastasio's arias and canzonettes are quite unequalled; and one is rather surprised to learn the mechanical coolness with which he was accustomed to set to work. Of the canzonette *La Partenza* and that to Nice, *Grazie agl' injanni tuoi*, are perhaps the finest, as they are the most celebrated.

Metastasio, late in life, counted forty editions of his works in his own library. The best are,—the Paris edition of 1755, in 9 vols. 8vo, published under the direction of Calsabigi; the Turin, 1757, 10 vols. 4to, founded on the former, and frequently reprinted till 1780, when the Herissant edition, in 12 vols. 4to, appeared at Paris, under the care of Pezzana, from a copy of the Turin edition corrected by the author. The Conte Pajala published the posthumous works at Vienna in 1795. The Genoa edition of 1802 and the Padua of 1811 are the most valuable. (W. H. C.)

METELLUS, the name of a noble family of the Cæcilian *gens*. Of this family the following are the most notable members:—

Quintus Cæcilius Metellus Macedonicus, who was appointed prætor in 148 B.C. Having received Macedonia as his province, he routed and captured Andriscus, the pretended king of that country. He then turned his arms against the Achæans, and encountering their prætor Critolaüs near Thermopylæ, gave him a severe defeat. After gaining a victory over the Arcadians near Chæroneia, he returned to Rome in 146 B.C., and was honoured with a triumph and with the surname of Macedonicus. Elected to the consulship in 143 B.C., Metellus was intrusted with the war against the Celtiberians in Nearer Spain. During the two years of this command he maintained with a steady hand the severest discipline among his soldiers, and the most skilful tactics against the enemy. His censorship in 131 B.C. was rendered notable by his proposing that every Roman should be forced by law to marry. The speech with which he introduced this motion was long afterwards read by Augustus in the senate, and has been partly preserved by A. Gellius in his *Noctes Atticæ*. Metellus lived to be universally respected, and to see his four sons enjoy the highest honours and the highest offices in the state. He died in 115 B.C., after exhibiting in his life a picture of human felicity which ancient writers have considered remarkable and almost unexampled.

Quintus Cæcilius Metellus Numidicus, who became consul in 109 B.C., and was sent into Numidia to carry on the war against Jugurtha. No sooner had he assumed the command than the Roman cause, which was formerly on the descendant, began forthwith to prosper. He routed the enemy near the River Mathal, ravaged the country without opposition, and by an artful system of intrigues kept the Numidian king in a restless terror for his life. In the following year, however, he was forced by the wary strategy of Jugurtha to protract the war. This delay was employed by his lieutenant, the ambitious Marius, to ruin his military reputation. The consequence was, that in a short time the low-born Marius superseded the aristocratic Metellus in the consulship and the command of the army. On his arrival at Rome in 107 B.C. Metellus was received with great applause, and was honoured with a triumph and with the title of Numidicus. During his censorship in 102 B.C. his zeal for the aristocracy led him to attempt to expel from the senate two inveterate plebeians Servilius Glaucia and Appuleius Saturninus. In 100 B.C. the latter obtaining the tribunate, returned the blow of Metellus, and by the aid of Marius, who was then consul, succeeded not only in depriving him of his seat in the senate, but in effecting his banishment. With cheerful resignation Metellus set out to Rhodes, carrying along with him his friend Ælius Præconinus, the rhetorician, and bent upon burying all gloomy thoughts in the deep problems of philosophy. He was roused, however, from his studies in the following year by the news that the popular party had suffered a severe check by the death of Saturninus, and that his own banishment was repealed. Not long after his return to Rome, Metellus is supposed to have been poisoned.

Metellus.

Quintus Cæcilius Metellus Pius, who received the surname of Pius from his affectionate endeavours to effect the recall of his father Numidicus from banishment. He was elected prætor in 89 B.C., and gained his first distinction as one of the leaders of the Marsic war. From carrying on hostilities against the Samnites he was summoned in 87 B.C. to defend Rome from Marius, who had returned from exile, and was marching towards the city to wreak vengeance on his enemies. Deeming it imprudent to dare so redoubtable a foe, Metellus repaired to Africa, and did not return to Italy till 84 B.C. He was among the first to greet Sulla on his landing at Brundusium in 83 B.C., and was one of the most effective lieutenants of that general in his protracted struggle with the Marian party. In 82 B.C. he gained three successive victories over the forces of Carbo; and in 79 B.C. he was sent as proconsul into Spain to check the victorious career of Sertorius. His ignorance, however, of that country, and the increasing infirmities of age, rendered him unfit to cope with the alert movements and guerilla strategy of his enemy. Only after a campaign of seven years was his military reputation redeemed by a victory over Sertorius. He returned to Rome in the following year to celebrate a triumph. Metellus Pius had been consul along with Sulla in 80 B.C., and he had also been appointed *pontifex maximus*. He died about 63 B.C.

Quintus Cæcilius Metellus Celer, who was elected to the prætorship in 63 B.C. In this capacity he was intrusted with the command of the three legions that guarded the Picentine and Senonian districts during the Catilinarian conspiracy. Anticipating the attempt of the rebel army to escape into Gaul, he threw himself into the passes of the Apennines, and thus compelled Catiline to turn back upon his pursuers, and to hazard that battle which issued in his defeat and death. In 60 B.C. Metellus was elected to the consulship, and exerted the entire power of his office in opposing the measures of Pompey, who was at that time considered the deadliest foe of the aristocracy. So determined, indeed, was his opposition, that he chose to be dragged to prison by order of the tribune rather than sanction an agrarian law for the provision of Pompey's soldiers. With the same unflinching resistance did he meet the agrarian law of Cæsar in 59 B.C. His death happened in the same year, not without raising suspicions that he had been poisoned by his wife Clodia, the profligate sister of Clodius.

Quintus Cæcilius Metellus Pius Scipio, who was the adopted son of Metellus Pius, and became tribune of the people in 59 B.C. In 52 B.C. Pompey took his daughter Cornelia in marriage, and chose himself as his colleague in the consulship. Metellus now became a puppet in the hands of his ambitious son-in-law. In 49 B.C. he proposed in the senate that Cæsar should be commanded to disband his troops, on pain of being treated as a public enemy. On the outbreak of the civil war which followed the execution of this proposal, the command in Syria was allotted to Metellus. No sooner had he taken possession of his province than his vicious character and his inability to govern burst forth into strong manifestation. The most exorbitant taxes were wrung from the people, the country was overrun by swarms of pillaging soldiers, and the blackest crimes passed unchallenged. From this scene of ruthless oppression he was summoned in 48 B.C. to play a part in the impending struggle between Pompey and Cæsar. He joined his son-in-law shortly after the skirmish at Dyrrhachium, and commencing forthwith to portion out the honours which the coming victory would leave at the disposal of his party, he became involved in a hot quarrel with some of his comrades touching his own claims to succeed Cæsar in the office of *pontifex maximus*. On the fatal day of Pharsalia he led the centre of the Pompeian army, and after he had seen his ambitious hopes scattered in the rout of his flying squadrons, he repaired to Africa to seek the aid of Juba, King of Numidia. The partizans of Pompey in that country placed him at their head. He was engaged in using his prerogative in his old practice of pillaging and oppressing when Cæsar arrived, towards the close of the year 47 B.C. In the following year Metellus was completely defeated at Thapsus. Escaping on board of a small fleet, he was intercepted by a squadron under P. Sittius, and was on the point of being captured when he stabbed himself, and then flung himself into the sea.

METEMPSYCHOSIS, a word of Greek origin signifying the passage or transmigration of souls, is applied to a peculiar system of doctrine, of high antiquity, respecting the destiny of the human soul. According to the more general forms of this system, the souls of men after death are supposed to enter successively into various bodies, and to animate various existences, which differ only in their external forms. It is equally difficult for man to believe in the ultimate annihilation of his spirit and to conceive of a future state of existence totally different from the present, independent alike of sense and of the laws of organized life. Accordingly, the mind seeks naturally for some mode of reconciling these two antagonistic conceptions—some system of faith, no matter how obscure, whereby "the longing after immortality" may be gratified, and the instinctive shrinking from annihilation find itself respected. And hence the origin of metempsychosis; the first form in which the doctrine of the immortality of the soul is presented to the human mind. Metempsychosis was maintained by the Egyptians, the Hindus, and the Greeks. Herodotus informs us (lib. ii., sec. 123), that the Egyptians were the first to adopt the doctrine of the soul's immortality; and it is generally to them that the invention of the metempsychosis is attributed. They held that the human soul immediately after death entered into some animal, called into existence at the same instant, and that after having successively assumed the forms of all the animals which inhabit the land, the water, and the air, it returned, after completing a cycle of 3000 years, into the body of a man, to recommence eternally the same endless pilgrimage. With the Hindus, again, the idea of metempsychosis is more metaphysical, more universal, than that of the Egyptians, and is closely allied to the idea of emanation maintained by that highly speculative race. As matter is the last degree of the emanations of Brahma, it follows that life, which is the union of the soul with matter, is essentially an evil. This being the case, all the developments of life, such as actions, sensations, pleasure, pain, &c., must of necessity share in the same degradation. Accordingly, the proper business of the soul is to die to everything earthly—to elevate itself by contemplation to that absolute repose in the bosom of the Deity from which it originally came forth. The soul must expiate in this world the sins of its previous life; and in order to purification, the impenitent are at death condemned to pass from one body into another of a more or less perfect form, according to the upward or downward tendency of their nature. Such is the doctrine taught in the philosophy of Vaisechika. According to the Vedanta system, again, the soul is not an emanation but a part of Brahma; a spark from an eternal fire. It knows neither birth nor death; it endues itself only for a time in a corporeal envelope, where it is afflicted by the darkness of ignorance, and subjected to the sufferings attendant upon evil. It visits various bodies in succession, and the circle of its metamorphoses embraces all organized nature, from a plant up to a man. Divine knowledge alone can extricate it from this circle of sorrow and humiliation; and this knowledge can only be attained by the soul stripping itself of all personality both of feeling and will; after which it precipitates itself into the bosom of the Deity, as a river discharges its waters into the sea.

It is a current belief that the idea of metempsychosis passed from Egypt into Greece; but this opinion is not well founded. For not only are traces of this doctrine to be found in the latter country, as the name of Orpheus will suggest, long previous to any authentic intercourse between those two nations, but Herodotus himself expressly distinguishes between the ancient and the modern partizans of metempsychosis in Greece; between the doctrine current in the country before the time of Pythagoras and the form of it introduced by that philosopher, who was the first Greek speculator initiated in the religious science of the Egyptian priests. But whether original or borrowed, the doctrine as found in Greece was in complete harmony with the genius of the Greek people. It was removed alike from the cloudy mysticism of India and from the miraculous naturalism of Egypt. It was Pythagoras who gave the doctrine its most precise form. He limited the metamorphoses of the soul to animal life, and, instead of a fortuitous entrance, he maintained that each individual soul passed into that particular form of organized animal existence which was most in harmony with its own faculties and condition.

Plato, in adopting this Pythagorean doctrine, attempts in the *Phædo* to establish it from two sources, and thus elevates it into the class of philosophical ideas. His first proof is drawn from the general order of nature, and the other from the human consciousness. Nature, says Plato, is governed by the law of contraries; death succeeds life, and life must succeed death. Again, we find evidence of the same state of pre-existence in the fact of reminiscence. That intellectual suggestiveness and inventive power so frequently noticeable in the subtler workings of the understanding, by which the mind makes such swift conquest of whole territories of the realm of knowledge, are only to be attributed to the fact that all this knowledge was once fully comprehended in a previous state of existence. But how far Plato insisted on this doctrine, or whether it was aught more than a piece of suggestive hypothesis, it is difficult to determine. We find the idea of metempsychosis assuming new developments during the later stages of Greek speculation. We encounter it subsequently in the school of Alexandria, in the bosom of Judaism, and in a father of the church. The hypothesis of a pre-existent state was, with Origen, a favourite mode of explaining certain biblical difficulties; and the same argument, particularly in its bearings on original sin, has been recently revived by an eminent American divine.

METEOROLITE. This term is derived from the Greek *μετεωρα*, *a meteor*, and *λιθος*, *a stone*, and denotes a stony substance, exhibiting peculiar characters, and the descent of which to the earth is usually accompanied by the appearance and explosion of a fire-ball.

Luminous meteors have in all ages been observed in the atmosphere. It is also well known that their disappearance has frequently been attended with a loud noise; but that they should moreover terminate in the fall of one or more solid bodies to the earth's surface, is a position so repugnant to our ordinary conceptions of the tenor of physical events, that we cannot admit it as a fact upon slight or scanty evidence.

One passage may be cited from the books of the Old Testament in corroboration of the descent of stones from the atmosphere. In the 11th verse of the 10th chapter of Joshua we find,—"And it came to pass, as they fled from before Israel, and were in the going down to Beth-horon, that the Lord cast down *great stones* from heaven upon them unto Azekah, and they died."

If from sacred we turn to the early period of profane history, we shall find the annals of public events very copiously interspersed with notices of such strange appearances. Through the midst of fable which envelopes the history of the *bætuli* we discern some characters which correspond with those of meteorolites. Thus in the *Λιθικα*, a poem falsely ascribed to Orpheus, the *σιδηριτης* is said to be "rough, heavy, and black." Damascius, in an extract of his Life of Isidorus, preserved by Photius, relates that the *bætuli* fell on Mount Libanus, in a "globe of fire." A fragment of Sanchoniathon, preserved by Eusebius in his *Præparatio Evangelii* (i. 10), moreover informs us, that these stones were fabricated by the god Uranus or Heaven, one of whose four sons was named Bætul. In the same chapter we are told that Astarte found a "star" which had "fallen from heaven," and honoured it with consecration in the city of Tyre. The stone denominated "the mother of the gods," if we can believe Appian, Herodian, and Marcellinus, "fell from heaven." Aristodemus, cited by the Greek scholiast on Pindar, asserts that it fell encircled by fire, upon a hill, at the feet of the Theban bard. It is said to have been of a black colour, and of an irregular shape. Herodian expressly declares, that the Phœnicians had no statue of the sun polished by the hand, but only a certain stone, circular below, and terminated acutely above, in the form of a cone, of a black colour, and that, according to report, it "fell from heaven," and was regarded by the people as the image of the sun.

Amongst various instances which might be selected from Livy is that of a shower of stones on the Alban Mount, in the reign of Tullus Hostilius, or about 652 B.C. The senate was assured that stones had really fallen, "haud aliter quam quum grandinem venti glomeratam in terras agunt."

But one of the most remarkable cases which occurs in the records of antiquity is that which is mentioned in the 58th chapter of the second book of Pliny's *Natural History*, of a large stone which fell near Ægospotamos in Thrace, in the second year of the 78th Olympiad, or, according to our chronology, about 467 years before the Christian era. Pliny assures us that this extraordinary mass was still shown in his day, and that it was as large as a cart, and of a burned colour. According to Plutarch, in the Life of Lysander, the inhabitants of the Chersonesus held the Thracian stone in great veneration, and exhibited it as a public show. This event is also recorded in that curious document, *The Parian Chronicle*, among the Arundelian marbles, in these terms—"From the time when *the stone fell* at Ægospotamos, and the poet Simonides died at the age of ninety, during the archonship of Theagenides at Athens, is 205 years." Pliny gives another instance of an aërolite which fell in Lucania about 56 B.C.; and Cæsar records the descent of another at Accilla 46 B.C.

From this period till near the close of the fifteenth century, any historical notices which we have been enabled to collect are so vague and scanty, that in this abridged view of the subject we may pass them over in silence.

Professor Bantenschoen, of the central school of Colmar, first directed the attention of naturalists to some of the old chronicles, which commemorate, with much naïveté, and in the true spirit of the times, the fall of the celebrated stone of Ensisheim. The following account accompanied this very singular mass when it was suspended in the church:—"In the year of the Lord 1492, on Wednesday, which was Martinmas eve, the 7th of November, there happened a singular miracle; for, between eleven o'clock and noon there was a loud peal of thunder, and a prolonged confused noise, which was heard to a great distance, and a stone fell from the air, in the jurisdiction of Ensisheim, which weighed 260 pounds, and the confused noise was, moreover, much louder than here. There a child saw it strike on a field situated in the upper jurisdiction, towards the Rhine and Inn, near to the district of Gisgard, which was sown with wheat; and did it no harm, except that it made a hole there; and then they conveyed it from that spot, and many pieces were broken from it, which the landvogt forbade. They therefore caused it to be placed in the church, with the intention of suspending it as a miracle, and many people came hither to see this stone."

Again, Trithemius, in his Hirsaugiensian Annals, employs language to this effect:—"In the same year, on the 7th day of November, in the village of Suntgaw, near the townlet of Ensisheim, not far from Basil, a city of Germany, a stone, called a thunder-stone, of a prodigious size, for we know from eye-witnesses that it weighed 255 pounds, fell from the heavens. Its fall was so violent that it broke into two pieces. The most considerable is still exhibited at the door of the church of Ensisheim, suspended by an iron chain, as a proof of the fact which we have mentioned, and to preserve it in the public recollection." We learn also from Paul Lang, "that there arose a furious storm on the 7th of November 1492, and that whilst the thunder roared, and the heavens appeared all on fire, a stone of enormous size fell near Ensisheim."

It is worthy of observation that these chroniclers lived at the period which they assign to the descent of the stone, and that although their names are hastening to oblivion, Trithemius yielded to few of his contemporaries in labour and learning; whilst Lang, a German Benedictine, had travelled in search of historical monuments, arraigned the license of the Catholic clergy, and applauded the independence of Luther and Melancthon.

In the Commentary of Surius, a Carthusian monk of Cologne, mention is made of a shower of large stones which fell in Lombardy in 1510. These stones were harder than flint, and smelled of sulphur. The heaviest weighed 120 pounds. The same event is more particularly related by Cardan, in his work entitled *De Rerum Varietate* (lib. xiv., c. 72). According to this author, near the River Adda, not far from Milan, and at five o'clock in the evening, about 1120 stones fell from the air, one of them weighing 120 pounds, and another 60 pounds. Many were presented to the French governor and his deputy. In the Memoirs of the Emperor Jehan-schah, written in Persian by himself, and translated by Colonel Kirkpatrick, is an account of the stone that fell in the province of Lahore in 1620; and Ferishta has recorded, in the true oriental style, the conversion of "this son of thunder," as he calls it, into two scimitars, a dagger, and a knife, by order of the emperor. The emperor says,—"Here I had this substance weighed in my presence. Its weight was 160 tolahs.[1] I committed it to a skilful artizan, with orders to make of it a sabre, a knife, and a dagger. The workman reported that the substance was not malleable, but shivered into pieces under the hammer. Upon this I ordered it to be mixed with other iron. Conformably to my orders, three parts of the *iron of lightning*[2] were mixed with one part of common iron, and from the mixture were made two sabres, one knife, and one dagger."

The celebrated Gassendi informs us, that on the 27th of November 1627, about ten o'clock in the morning, during a very clear sky, he saw a flaming stone, of the apparent diameter of 4 feet, fall on Mount Vaision, an eminence situated between the small towns of Perne and Guillaumes in Provence. This stone was surrounded by a luminous circle of different colours, nearly resembling the rainbow, and its fall was accompanied with a noise like the discharge of artillery. It weighed 59 pounds, and its specific gravity was to that of common marble as fourteen to eleven. It was of a dark metallic colour, and extremely hard. From a curious book printed at Paris in 1672, and now become very scarce, entitled "*Conversations tireés de l'Académie de M. l'Abbe Bourdelot contenant diverses Recherches et Observations Physiques, par le Sieur Legallois*, we make the ensuing extract:—"A member presents a fragment of two stones which fell near Verona, one of which weighed 300 and the other 200 pounds. These stones," says he, "fell during the night, when the weather was perfectly mild and serene. They seemed to be all on fire, and came from above, but in a slanting direction, and with a tremendous noise. This prodigy terribly alarmed 300 or 400 eye-witnesses, who were at a loss what to think of it."

No philosopher of the present day doubts the descent of stony bodies from the atmosphere; and the testimony of innumerable witnesses of their fall, with phenomena nearly similar, places *meteorolites* among the established facts of natural science. If several of the early notices of them are obscure, we have, in the end of the last and in the present century, many descriptions of their appearance, on their descent, by intelligent witnesses; so that scepticism on this subject can be no longer entertained. It is also very remarkable, that wherever they have fallen, in Europe, in India, or America, their composition is nearly identically the same, and agrees in composition with no known mineral. This has been established by the careful experiments of the Hon. Mr Howard, of Vauquelin, Laugier, Klaproth, and Berzelius, as well as by the investigations of Bournon and many other mineralogists. Their general composition may be stated as follows:—Silica, 40 per cent.; malleable iron, 25; nickel, from 6 to 8; with a small quantity of iron pyrites, and variable proportions of alumina, lime, magnesia, manganese; with traces of chrome, cobalt, and sulphur. In the present century many have fallen in France, Germany, India, and America; and in our own islands one fell in Yorkshire in 1795, another in Gloucestershire in 1835, a third near Glasgow in 1804, and two in Ireland from 1810 to 1813. We shall now proceed to more detailed instances.

We have now to direct our attention to a report of M. de Lalande, inserted in the *Historical Almanac* of Bresse for 1756. In the month of September 1753, about one o'clock afternoon, when the weather was very hot and very serene, without the least appearance of clouds, a very loud noise, like the discharge of two or three cannons, was heard within the circumference of six leagues, but was of very short duration. This noise was loudest in the neighbourhood of Pont-de-Vesle; and at Liponas, a village three leagues from the last-mentioned place, it was even accompanied with a hissing like that of a cracker. On the same evening there were found at Liponas and at Pin two blackish masses, of a form nearly circular, but very uneven, which had fallen on ploughed ground, and sunk by their own weight to the depth of half a foot below the surface. One of them weighed about twenty pounds; and a fragment of one of them, weighing eleven and a half pounds, was preserved in the cabinet of M. Varenne de Beost at Dijon. The basis of these masses resembled a grayish whinstone, and was very refractory; and some ferruginous particles were disseminated in grains, filaments, or minute masses, throughout the substance of the stone, especially in its fissures. On the 15th of September 1760, according to the Abbé Bachelay, about half-past four o'clock afternoon, there appeared near the Chateau de Chevabrie, in the neighbourhood of Luce, a small town of the province of Maine, a stormy cloud, from which proceeded a loud peal of thunder, like the discharge of cannon, and followed by a noise which was mistaken by several people for the lowing of oxen. This sound was heard over a space of about two leagues and a half, but unaccompanied by any perceptible flame. The reapers in the parish of Perigué, about three leagues from Luce, on hearing the same noise, looked up, and saw an opaque body, which described a curve, and fell on soft turf upon the high road from Mons, near which they were at work. They all quickly ran up to it, and found a sort of stone, nearly half of which was buried in the earth, and the whole so hot that it could not be touched. At first they ran away in a panic; but upon returning to the spot some time afterwards, they found the stone precisely in the same situation, and sufficiently cooled to admit of being handled and narrowly examined. It weighed seven ounces and a half, and was of a triangular form.

On the 20th of November 1768 a stone fell at Mauerkirchen, near the River Inn in Bavaria, which weighed 38 pounds, and was of a triangular form, being about eight inches in thickness. Its fall was accompanied by a hissing noise. The next remarkable case that has been recorded occurred on the 20th of August 1789 at Barbotan, near Roquefort, in the Landes of Bordeaux. A much more remarkable phenomenon, however, of the same description occurred near Agen on the 24th of July 1790. An inhabitant of St Sevère communicated the following particulars to M. Darcet the chemist, who was then resident at Paris:—"Our town's-people were yesterday very much alarmed. About a quarter-past nine o'clock in the evening there suddenly appeared in the atmosphere a fire-ball, dragging a long train, which diffused a very vivid light over the horizon. This meteor soon disappeared, and seemed to fall at one hundred paces from us. It was quickly followed by an explosion louder than that of a cannon or of thunder. Everybody dreaded being buried under the ruins of his house, which seemed to give way from the concussion. The same phenomenon was seen, and the report heard, in the neighbouring towns, as Mont de Marsan, Tartas, and Dax. The weather in other respects was very calm, without a breath of wind or a cloud, and the moon shone in all her brightness." Those which fell on the houses produced a noise, not like that of stones, but rather of a substance which had not yet acquired compactness.

M. Baudin mentions, that as M. Carris of Barbotan and he were walking in the court of the Castle of Mormes, about half-past nine o'clock in the evening of the 24th of July 1790, when the air was perfectly calm and the sky cloudless, they found themselves suddenly surrounded by a pale clear light, which obscured that of the moon, although the latter was nearly full. On looking up they observed, almost in their zenith, a fire-ball of a larger apparent diameter than that of the moon, dragging a tail which seemed to be five or six times longer than the diameter of its body, and which gradually tapered to a point; the latter approaching to blood-red, though the rest of the meteor was of a pale white. This luminous body proceeded with great velocity from south to north, and in two seconds split into portions of considerable size, like the fragments of a bursting bomb. These fragments became extinguished in the air, and some of them, as they fell, assumed that deep red colour which had been observed at the point of the tail. Two or three minutes afterwards M. Baudin and his friend heard a dreadful explosion, like the simultaneous firing of several pieces of ordnance; but they were not sensible of any tremulous motion under their feet, although the concussion of the atmosphere shook the windows in their frames, and threw down kitchen utensils from their shelves. When these gentlemen removed to the garden the noise still continued, and appeared to be directly over their heads. Some time after it had ceased, they heard a hollow sound rolling in echoes for about 50 miles along the chain of the Pyrenees, and at the end of about four minutes gradually dying away in distance. At the same time a strong sulphurous odour was diffused in the atmosphere. The interval which occurred between the disruption of the meteor and the loud report induced M. Baudin to conjecture that this fire-ball must have been at least 8 miles from the earth's surface, and that it fell about 4 miles from Mormes. "The latter part of my conjecture," says he, "was soon confirmed by an account which we received of a great many stones having fallen from the atmosphere at Juillac and in the neighbourhood of Barbotan." It appears, indeed, from the concurring testimony of intelligent persons worthy of credit, that the meteor really exploded at a little distance from Juillac, and that its fragments were found lying in an almost circular space of nearly 2 miles in diameter. Some of them weighed 18 or 20, and a few, it is alleged, even 50 pounds. M. de Carris procured one of 18 pounds, which he transmitted to the Academy of Sciences at Paris. That examined by M. Baudin was small, but heavy in proportion to its size, black on the outside, grayish within, and interspersed with many minute, shining, metallic particles.

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[1] A tolah is about 180 grains troy weight.

[2] This expression is equivalent to our term *thunderbolt*.

Our chronological series of cases has now brought us to the fall of several meteorolites near Sieña, the particulars of which, as reported by the Earl of Bristol and Sir William Hamilton, are recorded in the first part of the *Philosophical Transactions* for the year 1795 (p. 103). The date of the Sieña meteor is the 16th of June 1794. On the 13th of December in the following year, about three o'clock in the afternoon, another of these singular stones, weighing about 56 pounds, fell near the country-house of Captain Topham in Yorkshire. The captain's report, which is inserted in the *Gentleman's Magazine* for 1796, is distinct and satisfactory; whilst the chemical examination of the mass, detailed in Mr Howard's paper in the *Philosophical Transactions* for 1802, affords a still more decisive proof of its atmospheric origin. M. de Drée also found it to correspond exactly in aspect and character with fragments of meteoric stones from Benares and Ville-Franche. The original mass is larger than a man's head. It weighed 56 pounds, and is now in the British Museum.

Mr Southey, in his letters from Spain and Portugal, transcribes the authenticated relation of another instance of the descent of a stone from the clouds on the 19th of February 1796. But we pass to some of the most important details relative to the stone which is affirmed to have fallen near Ville-Franche, in the department of the Rhone, on the 12th of March 1798. It was transmitted to Professor Sage, member of the National Institute. "It is of an ash-gray colour," says M. Sage, "granulated, and speckled with gray, shining, and pyritous metallic points. One of its surfaces is covered with a dingy black enamel about the third of a line in thickness. This stone acts very powerfully on the magnetic needle."

An account of the same meteor was published in the *Journal de Physique* by M. de Drée. From his minute and deliberate investigation, it appears that the fire-ball had scarcely fixed the attention of the inhabitants of Sales and the adjacent villages, when its rapid approach, accompanied by a terrible whizzing noise, like that of an irregular hollow body traversing the air with unusual velocity, inspired the whole commune with alarm, especially when they observed it passing over their heads at an inconsiderable elevation. It left behind a long train of light, and emitted, with an almost unceasing crackling, small vivid flames like little stars. Its fall was remarked at the distance of only fifty paces by three labourers. These three witnesses attest the astonishing rapidity of the meteor's motion and the hissing which proceeded from the spot where it fell.

On the 19th of December 1798, about eight o'clock in the evening, the inhabitants of Benares and its neighbourhood observed in the heavens a very luminous meteor, in the form of a large ball of fire, which exploded with a loud noise, and from which a number of stones were precipitated near Krakhut, a village about 14 miles from the city of Benares. Mr Davis, the judge and magistrate of the district, affirmed that in brilliancy it equalled the brightest moonlight. "Of these stones," says Mr Howard, "I have seen eight nearly perfect: externally they were covered with a hard black coat or incrustation, which in some parts had the appearance of varnish or bitumen; and on most of them were fractures, which, from their being covered with a matter similar to that of the coat, seemed to have been made in the fall by the stones striking against each other, and to have passed through some medium, probably an intense heat, previous to their reaching the earth. Internally they consisted of a number of small spherical bodies of a slate colour, imbedded in a whitish gritty substance, interspersed with bright shining spiculæ, of a metallic or pyritical nature. The spherical bodies were much harder than the rest of the stone; the white gritty part readily crumbled on being rubbed with a hard body; and on being broken a quantity attached itself to the magnet, but more particularly the outside coat or crust, which appeared almost wholly attractable by it."

An account of the extraordinary shower of stones which fell near L'Aigle in Normandy, on 26th April 1803, appeared in the following letter addressed by M. Marais, an inhabitant of the place, to his friend in Paris:—"An astonishing miracle has just occurred in our district. Here it is, without alteration, addition, or diminution. It is certain that it is the truth itself. On Friday (26th of April), between one and two o'clock in the afternoon, we were roused by a murmuring noise like thunder. On going out we were surprised to see the sky pretty clear, with the exception of some small clouds. We took it for the noise of a carriage or of fire in the neighbourhood. We were then in the meadow, to examine whence the noise proceeded, when we observed all the inhabitants of the Pont de Pierre at their windows and in gardens, inquiring concerning a cloud which passed in the direction of from S. to N., and from whence the noise issued, although that cloud presented nothing extraordinary in its appearance. But great was our astonishment when we learned that many and large stones had fallen from it, some of them weighing 10, 11, and even 17 pounds, in the space between the house of the Buat family (half a league to the N.N.E. of L'Aigle) and Glos, passing by St Nicolas, St Pierre, &c., which struck us at first as a fable, but which was afterwards found to be true. The following is the explanation given of this extraordinary event by all who witnessed it:—They heard a noise like that of a cannon, then a double report still louder than the preceding, followed by a rumbling noise, which lasted about ten minutes, the same which we also heard, accompanied with hissings, caused by these stones, which were counteracted in their fall by the different currents of air, which is very natural in the case of such a sudden expansion. Nothing more was heard; but it is remarkable that, previously to the explosion, the domestic fowls were alarmed, and the cows bellowed in an unusual manner. All the country people were much dismayed, especially the women, who believed that the end of the world was at hand. A labourer at La Sapée fell prostrate on the ground, exclaiming, 'Good God, is it possible that thou canst make me perish thus? Pardon, I beseech thee, all the faults I have committed.' The most trifling objects, in fact, might create alarm; for it is not improbable that history offers no example of such a shower of stones as this. The piece which I send was detached from a large one weighing about 11 pounds, which was found between the house of the Buats and Le Fertey. It is said that a collector of curiosities purchased one of 17 pounds weight that he might send it to Paris. Everybody in this part of the country is desirous of possessing a whole stone, or a fragment of one, as an object of curiosity."

At the sitting of the Institute on the 9th of May, Fourcroy read a letter from L'Aigle addressed to M. Vauquelin, and which sufficiently corroborates the preceding statements. But we pass to the substance of M. Biot's letter addressed to the minister of the interior, and published in the *Journal des Débats*. This very eminent philosopher was deputed by government to repair to the spot, and collect all the authentic facts. He left Paris on the 5th of June, and instead of proceeding directly to L'Aigle, went first to Alençon, which lies 15 leagues to the W.S.W. of that place. He was informed on his way that a globe of fire had been observed moving towards the north, and that its appearance was followed by a violent explosion. From Alençon he journeyed through various villages to L'Aigle, being directed in his progress by the accounts of the inhabitants, who had all heard the explosion on the day and at the hour specified. Almost all the inhabitants of twenty hamlets, scattered over an extent of upwards of 2 square leagues, affirmed that they were eye-witnesses of a dreadful shower of stones which were darted from the meteor. The following is his summary of the whole evidence:—"On Tuesday, 6th Floreal, year 11, about one o'clock P.M., the weather being serene, there was observed from Caen, Pont d'Audemer, and the environs of Alençon, Falaise, and Verneuil, a fiery globe of a very brilliant splendour, and which moved in the atmosphere with great rapidity. Some moments after there was heard at L'Aigle, and in the environs of that town, in the extent of more than 30 leagues in every direction, a violent explosion which lasted five or six minutes. At first there were three or four reports like those of cannon, followed by a kind of discharge which resembled the firing of musketry; after which there was heard a dreadful rumbling like the beating of a drum. The air was calm and the sky serene, except a few clouds, such as are frequently observed. . This noise proceeded from a small cloud which had a rectangular form, the largest side being in a direction from E. to W. It appeared motionless all the time that the phenomenon lasted; but the vapours of which it was composed were projected momentarily from different sides by the effect of the successive explosions. This cloud was about half a league to the N.N.W. of the town of L'Aigle. It was at a considerable elevation in the atmosphere, for the inhabitants of two hamlets, a league distant from each other, saw it at the same time above their heads. In the whole canton over which this cloud was suspended, there was heard a hissing noise like that of a stone discharged from a sling, and a great many mineral masses, exactly similar to those distinguished by the name of *meteoric stones,* were seen to fall. The district in which these masses were projected forms an elliptical extent of about 2½ leagues in length, and nearly 1 in breadth, the greatest dimension being in a direction from S.E. to N.W. forming a declination of about 22 degrees. This direction, which the meteor must have followed, is exactly that of the magnetic meridian, which is a remarkable result. The greatest of these stones fell at the south-eastern extremity of the large axis of the ellipse, the middle-sized in the centre, and the smaller at the other extremity. Hence it appears that the largest fell first, as might naturally be supposed. The largest of all those that fell weighs 17½ pounds. The smallest which I have seen weighs about 2 gros (a thousandth part of the last). The number of all those which fell is certainly above two or three thousand."

It deserves to be remarked, that the L'Aigle stones were very friable for some days after their descent, that they gradually acquired hardness, and that after they had lost the sulphurous odour on their surface, they still retained it in their substances, as was found by breaking them. That some of the relations to which we have referred are vague and unsatisfactory cannot be denied, but the circumstantial testimony conveyed by others is pointed and positive; and the whole mass of historical proof, especially when combined with the argument deduced from the identity of the physical and chemical constitution of the stones, appears to us to be altogether irresistible.

In the course of our inquiry into this novel and interesting subject we have ascertained a variety of circumstances which render it highly probable, if not indubitable, that those detached masses of native iron, the history of which has so often staggered and perplexed the geologist, are only modifications of meteoric depositions. The Tartars, for example, ascribe the descent of the Siberian mass described by Pallas, Chladni, and others, to a period that is lost in the remoteness of antiquity; and whilst tradition thus favours our hypothesis, the analogy which is obviously observable, in point of texture and chemical characters, with those of other solid bodies the fall of which is no longer questioned, strengthens tradition. According to the discoveries of Proust and Klaproth, native iron, reputed meteoric, differs from that which occurs in a fossil state by the presence of nickel. The former of these celebrated analysts obtained 50 grains of sulphate of nickel from 100 of the South American mass, and his results are corroborated by Mr Howard and the Count de Bournon.

Of the two pieces of Siberian iron now in the British Museum, one of which was transmitted by Dr Pallas, weighs several pounds; and another presents a cellular and ramified texture analogous to that of some very light and porous volcanic scoriæ. When attentively examined, there may be perceived in it not only empty cells, but also impressions or cavities of greater or less depth, and in some of which there remain specks of olivine. The iron itself is very malleable, and may be easily cut with a knife or flattened under the hammer. The specific gravity is 6487, which is obviously inferior to that of unforged iron that has undergone fusion, and may be partly owing to the oxidizement of the surface of the iron, and partly to the many minute cavities in its substance, which are often rendered visible by fracture, and which have their surface also oxidized. The fracture is shining and silvery, like that of white cast-iron; but its grain is much smoother and finer, and it is much more malleable when cold. The heavier specimen is more solid and compact, exhibiting no cavities or pores, though its surface is ramified and cellular. So blended and incorporated is its compact part with the olivine mentioned above, that if the whole of the latter could be subtracted, the remainder would consist of iron in the metallic state, and would display the same cellular appearance as the preceding specimen, or as the superficial portion of that now described. "I cannot help observing," says the Count de Bournon, "that there appears to exist a very interesting analogy between these transparent nodules and the globules I described as making part of the stones said to have fallen on the earth. This analogy, though not a very strong one, may lead us to suppose that the two substances are similar in their nature, but that the globules are less pure, and contain a greater quantity of iron."

Having now, as we apprehend, sufficiently established the existence and nature of meteorolites, we hope that our readers will excuse us from enlarging on the various causes which have been assigned for their origin, as these seem to lie beyond the reach of our present state of knowledge. After a candid and patient review of the principal theories, we conceive that most of them are open to many and formidable objections.

The terrestrial hypotheses, we believe, begin already to be generally abandoned as untenable. Until the phenomenon of exploding meteors had been distinctly observed and recorded, Lemery and others could maintain, with some degree of plausibility, that lightning might tear up the ground, and convert soil into a compact mass. But the appearances of a thunder-storm and of a fire-ball are now ascertained to differ in various important particulars. Spectators worthy of credit have seen the latter terminate in the fall of solid bodies, and the composition of these solid bodies has been found to differ from that of all the known fossil substances on the surface of the globe. It is in vain, then, to allege that they are formed on the ground by common lightning, which has often produced very extraordinary effects, but which never generated thousands of stones in fine calm weather. The supposition that such stones have been projected from some of our volcanoes is hardly less conceivable. The ashes which accompany a violent eruption of Ætna or Vesuvius have, from their levity, been carried to a very considerable distance; but we are totally unacquainted with any projectile force which could dart solid masses many hundred miles through such a dense medium as the atmosphere. The compact lavas of burning mountains are never found remote from the scene of their formation, and none of them present the characters and aspect of the stones which we have described. Of those who contend for the *atmospherical* formation of meteorolites, scarcely any two agree in regard to the manner in which such formation is effected. The celebrated Muschenbroeck in one part of his writings ascribes the descent of stones from the air to earthquakes and volcanic eruptions; an opinion which later observations have disproved. In other passages, however, he seems to incline to a modification of the atmospherical hypothesis, and endeavours to trace the origin of shooting stars to an accumulation of the volatile matters which are suspended in the air. M. Salverte has given extension to the theory of formation from vapours by having recourse to the agency of hydrogen gas. According to him, in consequence of the decomposition of water, which is constantly going on at the surface of the earth, immense quantities of hydrogen gas are continually rising into the atmosphere, and ascending to its higher regions. As this gas is capable of dissolving metals, it carries along with it a portion of iron and nickel. During thunder-storms this gas is kindled by electricity; the metals are deposited, reduced, melted, and vitrified; in other words, meteors are produced and stones formed. But this hypothesis is scarcely more satisfactory than the others. It does not account for the presence of magnesia and silica, nor does it explain why the stones are always composed of the same materials. In general we may observe, that if the origin of meteorolites be really atmospherical, the matters of which they are composed must have existed in one of two states, namely, in very attenuated particles or concretions of the matters themselves volatilized and held in solution in the air, or only in the *elements* of these matters. In the first case, when abandoned by their menstruum to their reciprocal tendencies, they would unite by aggregation only; in the second, by chemical combination. M. Izarn, who has published a treatise on *Atmospherical Lithology*, has entered into a somewhat obscure exposition of his own theory, founded on this principle. We shall give the summary, as nearly as we can, in his own words:—

"Gaseous substances, arranged in spherical masses in the upper regions of the air, being admitted, the various agitations of the atmosphere should naturally waft some of these masses from their insulating medium into one capable of combining with them. If the combination begins, the disengagement of light is explained. In proportion as the combination advances the specific gravities are changed, and consequently a change of place will commence. Motion being once impressed, the mass traverses other media, capable of supplying new principles, which, still increasing the weight, determine the curve; and when at length the principles which are at work have attained the requisite proportion for extinguishing the elements in the birth of the compound, the grand operation is announced by the explosion, and the product takes its place among the solids." That the stones in question are produced by chemical combination in the higher regions of the atmosphere, and that they are thus formed from their own elements, are suppositions fully as probable as any that have been advanced on the subject; but whether the union of their parts be effected in the manner detailed by M. Izarn we are unable to determine, because our range of data is as yet too circumscribed to warrant any specific or decisive conclusions.

A much bolder theory has been suggested, and its *possibility* demonstrated, by Laplace, who shows that meteorolites may be the products of lunar volcanoes. We shall present the reasoning upon which this extraordinary hypothesis is founded, in the popular and perspicuous language of Dr Hutton of Woolwich. The respect due to the name of Laplace will justify the length of the extract. "As the attraction of gravitation extends through the whole planetary system, a body placed at the surface of the moon is affected chiefly by two forces, one drawing it toward the centre of the earth, and another drawing it toward that of the moon. The latter of these forces, however, near the moon's surface, is incomparably the greater. But as we recede from the moon, and approach toward the earth, this force decreases, whilst the other augments; till at last a point of station is found between the two planets, where these forces are exactly equal, so that a body placed there must remain at rest; but if it be removed still nearer to the earth, then this planet would have the superior attraction, and the body must fall towards it. If a body, then, be projected from the moon towards the earth, with a force sufficient to carry it beyond the point of equal attraction, it must necessarily fall on the earth. Such, then, is the idea of the manner in which the bodies must be made to pass from the moon to the earth, if that can be done, the *possibility* of which is now necessary to be considered. Now, supposing a mass to be projected from the moon, in a direct line towards the earth, by a volcano or by the production of steam by subterranean heat; and supposing, for the present, these two planets to remain at rest; then it has been demonstrated, on the Newtonian estimation of the moon's mass, that a force projecting the body with a velocity of 12,000 feet in a second would be sufficient to carry it beyond the point of equal attraction. But this estimate of the moon's mass is now allowed to be much above the truth; and, on M. Laplace's calculation, it appears that a force of little more than half the above power would be sufficient to produce the effect; that is, a force capable of projecting a body with a velocity of less than a mile and a half per second. But we have known cannon-balls projected by the force of gunpowder with a velocity of 2500 feet per second or upwards; that is, about half a mile. It follows, therefore, that a projectile force, communicating a velocity about three times that of a cannon-ball, would be sufficient to throw the body from the moon beyond the point of equal attraction, and cause it to reach the earth. Now there can be little doubt that a force equal to that is exerted by volcanoes on the earth, as well as by the production of steam by subterranean heat, when we consider the huge masses of rock, so many times larger than cannon-balls, thrown on such occasions to heights also so much greater. We may easily imagine, too, such cause of motion to exist in the moon as well as in the earth, and that in a superior degree, if we may judge from the supposed symptoms of volcanoes recently observed in the moon by the powerful tubes of Dr Herschel; and still more, if we consider that all projections from the earth suffer an enormous resistance and diminution by the dense atmosphere of this planet, whilst it has been rendered probable, from optical considerations, that the moon has little or no atmosphere at all to give any such resistance to projectiles.

"Thus, then, we are fully authorized in concluding that the case of *possibility* is completely made out; that a known power exists in nature capable of producing the foregoing effect, of detaching a mass of matter from the moon, and transferring it to the earth in the form of a flaming meteor or burning stone: at the same time we are utterly ignorant of any other process in nature by which the same phenomenon can be produced. Having thus discovered a way in which it is possible to produce those appearances, we shall now endeavour to show, from all the concomitant circumstances, that these accord exceedingly well with the natural effects of the supposed cause, and thence give it a very high degree of *probability*.

"This important desideratum will perhaps be best attained by examining the consequences of a substance supposed to be projected by a volcano from the moon into the sphere of the earth's superior attraction, and then comparing those with the known and visible phenomena of the blazing meteors or burning stones that fall through the air on the earth. And if in this comparison a striking coincidence or resemblance shall always or mostly be found, it will be difficult for the human mind to resist the persuasion that the assumed cause involves a degree of probability but little short of certainty itself. Now the chief phenomena attending these blazing meteors or burning stones are these: 1. That they appear to blaze out suddenly; 2. That they move with a surprisingly rapid motion, nearly horizontal, but a little inclined downwards; 3. That they move in several different directions with respect to the points of the compass; 4. That in their flight they yield a loud whizzing sound; 5. That they commonly burst with a violent explosion and report; 6. That they fall on the earth, with great force, in a sloping direction; 7. That they are very hot at first, remain hot a considerable time, and exhibit visible tokens of fusion on their surface; 8. That the fallen stony masses have all the same external appearance and contexture, as well as internally the same nature and composition; and, 9. That they are totally different from all our terrestrial bodies, both natural and artificial.

"Now these phenomena we shall proceed to compare with the circumstances of a substance projected by a lunar volcano, and in the order in which they are here enumerated. And, first, with respect to the leading circumstance, that of a sudden blazing meteoric appearance, which is not that of a small bright spark, first seen at an immense distance, and then gradually increasing with the diminution of its distance. And this circumstance appears very naturally to result from the assumed cause. For, the body being projected from a lunar volcano, may well be supposed in an ignited state, like inflamed matter thrown up by our terrestrial volcanoes, which, passing through the comparatively vacuum in the space between the moon and the earth's sensible atmosphere, it will probably enter the superior parts of this atmosphere with but little diminution of its original heat; from which circumstance, united with that of its violent motion, this being ten or twelve times that of a cannon-ball, and through a part of the atmosphere probably consisting chiefly of the inflammable gas rising from the earth to the top of the atmosphere, the body may well be supposed to be suddenly inflamed, as the natural effect of these circumstances; indeed it would be surprising if it did not. From whence it appears, that the sudden inflammation of the body on entering the earth's atmosphere is exactly what might be expected to happen.

"2. To trace the body through the earth's atmosphere, we are to observe that it enters the top of it with the great velocity acquired by descending from the point of equal attraction, which is such as would carry the body to the earth's surface in a very few additional seconds of time if it met with no obstruction. But as it enters deeper in the atmosphere, it meets with still more and more resistance from the increasing density of the air, by which the great velocity of 6 miles per second must soon be greatly reduced to one that will be uniform, and only a small part of its former great velocity. This remaining part of its motion will be various in different bodies, being more or less as the body is larger or smaller, and as it is more or less specifically heavy; but for a particular instance, if the body were a globe of 12 inches diameter, and of the same gravity as the atmospheric stones, the motion would decrease so as to be little more than a quarter of a mile per second of perpendicular descent. Now, whilst the body is thus descending, the earth itself is affected by a twofold motion, both the diurnal and the annual one, with both of which the descent of the body is to be compounded. The earth's motion of rotation at the equator is about 17 miles in a minute, or two-sevenths of a mile in a second; but in the middle latitudes of Europe little more than the half of that, or little above half a quarter of a mile, in a second; and if we compound this motion with that of the descending body, as in mechanics, this may cause the body to appear to descend obliquely, though but a little, the motion being nearer the perpendicular than the horizontal direction. But the other motion of the earth, or that in its annual course, is about 20 miles in a second, which is eighty times greater than the perpendicular descent in the instance above mentioned; so that, if this motion be compounded with the descending one of the body, it must necessarily give it the appearance of a very rapid motion in a direction nearly parallel to the horizon, but a little declining downwards; a circumstance which exactly agrees with the appearances of these meteoric bodies, as stated in the second article of the enumerated phenomena.

"3. Again, with regard to the apparent direction of the body; this will evidently be various, being that compounded of the body's descent and the direction of the earth's annual motion at the time of the fall, which is itself various in the different seasons of the year, according to the direction of the several points of the ecliptic to the earth's meridian or axis. Usually, however, from the great excess of the earth's motion above that of the falling body, the direction of this must appear to be nearly opposite to that of the former. And, in fact, this exactly agrees with a remark made by Dr Halley, in his account of the meteors in his paper above given, where he says that the direction of the meteor's motion was exactly opposite to that of the earth in her orbit. And if this shall generally be found to be the case, it will prove a powerful confirmation of this theory of the lunar substances. Unfortunately, however, the observations on this point are very few, and mostly inaccurate; the angle or direction of the fallen stones has not been recorded, and that of the flying meteor commonly mistaken; all the various observers giving it a different course, some even directly the reverse of others. In future it will be very advisable that the observers of fallen stones observe and record the direction or bearing of the perforation made by the body in the earth, which will give us perhaps the course of the path nearer than any other observation.

"4. In the flight of these meteoric stones it is commonly observed that they yield a loud whizzing sound. Indeed it would be surprising if they did not. For if the like sound be given by the smooth and regularly-formed cannon-ball, and heard at a considerable distance, how exceedingly great must be that of a body so much larger, which is of an irregular form and surface, too, and striking the air with fifty or a hundred times the velocity.

"5. That they commonly burst and fly in pieces in their rapid flight is a circumstance exceedingly likely to happen, both from the violent state of fusion on their surface, and from the extreme rapidity of their motion through the air. If a grinding-stone, from its quick rotation, be sometimes burst, and fly in pieces, and if the same thing happen to cannon-balls when made of stone and discharged with considerable velocity, merely by the friction and resistance of the air, how much more is the same to be expected to happen to the atmospheric stones, moving with more than fifty times the velocity, and when their surface may well be supposed to be partly loosened or dissolved by the extremity of the heat there.

"6. That the stones strike the ground with a great force, and penetrate to a considerable depth, as is usually observed, is a circumstance only to be expected from the extreme rapidity of their motion and their great weight, when we consider that a cannon-ball or a mortar-shell will often bury itself many inches, or even some feet, in the earth.

"7. That these stones, when soon sought after and found, are hot, and exhibit the marks of recent fusion, are also the natural consequences of the extreme degree of inflammation in which their surface had been put during their flight through the air.

"8. That these stony masses have all the same external appearance and contexture, as well as internally the same nature and composition, are circumstances that strongly point out an identity of origin, whatever may be the cause to which they owe so generally uniform a conformation. And when it is considered,

"9. That in those respects they differ totally from all terrestrial compositions hitherto known or discovered, they lead the mind strongly to ascribe them to some other origin than the earth we inhabit; and none so likely as coming from our neighbouring planet.

"Upon the whole, then," continues Dr Hutton, "it appears highly probable that the flaming meteors and the burning stones that fall on the earth are one and the same thing. It also appears impossible, or in the extremest degree improbable, to ascribe these either to a formation in the superior parts of the atmosphere, or to the eruptions of terrestrial volcanoes, or to the generation by lightning striking the earth. But, on the other hand, that it is possible for such masses to be projected from the moon so as to reach the earth, and that all the phenomena of these meteors or falling stones, having a surprising conformity with the circumstances of masses that may be expelled from the moon by natural causes, unite in forming a body of strong evidence that this is in all probability actually the case."

M. Poisson, a very ingenious French mathematician, has shown, by an algebraical calculation, the possibility of a projectile reaching our planet from the moon. His calculation, however, which may be found in the work of Izarn quoted above, proceeds on the supposition that our satellite has no atmosphere, or next to none. There are, no doubt, appearances which seem to favour this supposition, but they do not amount to positive proof of the fact.

The hypothesis of Dr Chladni, which likewise boasts of its advocates, deserves to be stated. As earthy, metallic, and other particles form the principal component parts of our planet, amongst which iron is the prevailing part, other planetary bodies, he affirms, may consist of similar, or perhaps the same, component parts, though combined and modified in a very different manner. There may also be dense matters accumulated in smaller masses, without being in immediate connection with the larger planetary bodies, dispersed throughout infinite space, and which being impelled either by some projecting power or attraction, continue to move until they approach the earth or some other body, when, being overcome by attractive force, they immediately fall down. By their exceeding great velocity, which is increased by the attraction of the earth and the violent friction in the atmosphere, a strong electricity and heat must necessarily be excited, by which means they are reduced to a flaming and melted condition, and great quantities of vapour and different kinds of gases are thus disengaged, which distend the liquid mass to a monstrous size, until, by still further expansion of these elastic fluids, they must at length displode.

Such are the principal hypotheses which have been advanced on the origin of meteorolites. We shall conclude this article by a list of these bodies contained in the British Museum.

Aerolites in the British Museum, with Time and Place of their descent, when known.

Ensisheim, 1492; Reichstadt, Bohemia, 1723; Bechin, Bohemia, 1753; Agram, Croatia, 1754; Saharampore, Delhi, 1758; Maurkirchen, Austria, 1768; Bobric, Chazkow, 1787; Sieña, Italy, 1794; Thwing, Yorkshire, 1795; Sales, France, 1798; Benares, India, 1798; L'Aigle, France, 1803; Borgo, Parma, 1804; Possil, near Glasgow, 1804; Timochin, Russia, 1807; Weston, Connecticut, 1807; Casignano, Parma, 1808; Stannern, Moravia, 1808; Tipperary, Ireland, 1810; Berlanguillas, Spain, 1811; La Vendée, France, 1812; Adare, Limerick; 1813; Wiburg, Finland, 1814; Agen, France, 1814; Chassigny, France, 1815; North Carolina, America, 1816; Joussac, France, 1819; Juvènas, France, 1821; Nanjemoy, Maryland, 1825; Sandwich Islands, 1825: Nashville, Tennessee, 1827; Chesterfield, Virginia, 1828; Berar, India, 1828; Charvallas, India, 1834; Tennessee, 1835; Aldworth, Gloucestershire, 1835; Bokkeveld, Cape of Good Hope, 1838; Little Piney, Missouri, 1839; Triguerre, France, 1841; Carthage, Tennessee, 1847; Bishopville, South Carolina, 1847; Cabarras, North Carolina, 1849.

Fragments of Meteoric Iron, date of fall unknown.

1. Part of the Otumpa mass sent from South America by Sir Woodbine Parish,—it weighs 1400 lb.; 2. Part of the Siberian mass of Pallas; 3. Aix-la-Chapelle; 4. Tennessee; 5. Alabama; 6. Kamisdorf, Saxony; 7. Lockport, New York; 8. Red River, Texas; 9. Arva, Hungary; 10. Elbogen, Bohemia; 11. Cape of Good Hope; 12. Heidelberg; 13. Durango, Mexico; 14. Zacatecas, do.; 15. Xiquipilco, do.; 16. Atacama, Bolivia; 17. Gran-Chaco, Peru; 18. Lenarto, Hungary; 19. Green County, Tennessee; 20. Benidego, Brazil; 21. Senegal; 22. Kentucky; 23. Cocke County, Tennessee; 24. Læsegen Lake, Brandenburg; 25. Colima di Brianza, Milan; 26. Esquimeaux knives of meteoric iron, brought by Captain Ross from Lat. 76. 12. N., Long. 53. W.

For further information on the subject of this article, see Izarn's *Lithologie Atmosphérique;* Biot's *Relation d'un Voyage fait dans le Departement de l'Orne, pour constater la réalité d'un Météore observé à L'Aigle;* Böttiger's *Observations on the Accounts given by Ancient Authors of Stones said to have fallen from the Clouds;* Fulda's *Memoir on Fire-Balls;* Cavallo's *Elements of Natural Philosophy;* Klaproth *on Meteoric Stones;* Soldani's *Account of the Tuscan Meteor;* Chladni's *Treatise on the Siberian Mass of Iron;* Mr Edward King's *Remarks concerning Stones said to have fallen from the Clouds;* and the Transactions of several learned societies. (L. M.)

METEOROLOGY.

(1.) METEOROLOGY, which, in its ancient and etymological sense, included all the appearances of the heavens, as well astronomical as atmospheric, is at present restricted in its meaning to the description and explanation of that class of phenomena which group themselves under the heads of the weather, of the seasons, and of climate—phenomena which, scientifically regarded, are referable almost entirely to the investigation of those laws which govern the ever-varying affections of the atmosphere of our globe in its relations to heat, moisture, and electricity, and the movements which the changes of those relations, brought about by astronomical or other causes, impress upon its parts.

(2.) Were it not for this last-mentioned class of relations, those, namely, which depend on the mobility of our atmosphere, and the consequent perpetual local interchange of its parts more or less heated, and more or less moist, *inter se*, the problems presented by meteorology would be of a very simple nature. Whatever be the temperature of the interior of our globe (and there is every reason to believe it very high), it has been amply demonstrated, that the escape of its internal heat into space through its surface, for many ages past and to come, may be regarded as uniform, and so excessively slow as to be quite inappreciable as a cause of any portion of the temperature prevalent on the surface, still more so of any variation in that element. Local conflagrations and volcanoes (whatever influence geologists may ascribe to the latter in earlier states of our planet) are absolutely insignificant at present for the supply of warmth, so that it is to the sun alone that we have to look as the ultimate source of heat, and therefore also, in all probability, of electrical excitement. Supposing, then, no lateral communication or transfer between the columns of air incumbent on adjacent parts of the earth's surface, the totality of atmospheric and climatic change in any given locality would be limited to periodical and perfectly regular fluctuations of temperature depending on the direct heating power of the sun at its various altitudes above the horizon during the day, and its withdrawal during the night, and to the ultimate generation and condensation of vapour equally periodic and regular, immediately consequent on such fluctuations, over those parts of the surface occupied by water. No rain would ever fall on, or cloud form over, any part of the land, which would be perfectly arid, and dependent for its temperature, at any spot, on the greater or less aptitude of its materials at that spot for absorbing and retaining the sun's rays. It is needless to add that, under such circumstances, the ocean only would possess the conditions indispensable to animal or vegetable life.

(3.) The mobility of the air, while it destroys this simplicity of sequence, and substitutes for it the variety and complexity of phenomena we actually observe, lands us, while seeking for their explanation, among mechanical difficulties of a very high order. If there be one part of dynamical science more abstruse and unapproachable than another, it is the doctrine of the propagation of motion in fluids, and especially in elastic fluids like the air, even when the amount and application of the original acting forces are known and calculable. But in this case, the acting forces consist in local dilatations of parts of the atmosphere by the sun's heat during the day, and contractions by cold during the night—in the permanent difference of temperature in the equatorial and polar regions—in the evaporation of moisture in some parts, and its precipitation in rain in others, which act directly as a motive force, displacing air, and indirectly by carrying heat in a latent form from one region to another. And as if the problems arising out of these considerations alone were not sufficiently complex and intractable, the occupation of one part of the surface of our globe by land and another by sea, differing as they do in their relations to heat, in their evaporation of moisture, and in their resistance to the motion of bodies of air passing over them; the irregular form of the continents, and the existence on them of mountain chains which confine, obstruct, and divert the free courses of aerial currents—all concur to fill the subject of meteorology with difficulties utterly insurmountable if attacked by those methods of calculation which have proved so signally successful in many other branches of science.

(4.) And yet it is these very difficulties, and this excessive complication, which, by forcing us to abandon the *deductive* mode of philosophizing from sheer inadequacy of methods, throws us on the opposite, or *inductive* course of inquiry in the very attitude most favourable to success. For it is not because the general principles of dynamics are *inapplicable* to the subject that we are deterred from resorting to them as our sole dependence, but because we neither possess data sufficiently wide and precise to afford ground for their application, nor command enough of them as instruments to grapple with such data in all their particularity if we had them. In our assurance of their *general applicability*, we possess an invaluable clue, which precludes all groping in the dark for causes, and which serves at every step to direct the course our induction ought to take, and the forms in which it is desirable that our acquirements should be invested so as to be most available for constructing a complete theory. We come to the subject, in short, as we have every reason to believe, with a clear apprehension of all the principal efficient causes, and a pretty distinct conception of their *direct* action. It is the number and simultaneous operation of their derivative causes, the immense influence and complication of their *indirect* actions, which constitute the difficulty of this branch of physics. But, on the other hand, our knowledge of these causes throws the whole burden of the inquiry on the discovery of subordinate or derivative laws, and never leaves us at a loss (as in so many other departments of physical research) for the interpretation of those laws when discovered, or for the best and most philosophical way of expressing them in terms conveying their true theoretical import.

(5.) And hence arises one of the most marked peculiarities of this our science, viz., that while in respect of the general explanation of its phenomena it may be said to be nearly complete, inasmuch as there are few of its more important facts and broad features which cannot be rationally and satisfactorily accounted for, and referred to the recognized operations of physical agents, yet when we would follow out the results of their actions in "number, weight, and measure," and as exhibited in specified time and place, theory affords us little or no assistance. Meteorology, in short, in all that concerns numerical valuation, is pre-eminently a science of detail, and one in which all the subordinate laws which are susceptible of numerical statement have to be made out by laborious and continued observation carried on in every region of the globe. The results of such observation, accumulated in masses, and discussed by the application of those powerful and refined processes of calculation which modern invention has devised, become cleared of accidental error, freed from the influence of transient and purely local causes of irregularity, and presented in the form of mean or average conclusions, each expressing some general fact or law of progressive change. Thus, while on the one hand *deductive* theory, based on our knowledge of the acting causes and the circumstances under which they act, pursues their operation clearly to a certain extent, and less and less distinctly as it becomes lost in their entanglement; it is yet enabled to point out the directions where light is to be looked for, the lines of inquiry which *inductive* observation ought to pursue, and the form of the results which it ought to aim at securing.

(6.) The course we shall follow in the present article will be in accordance with this general view of the subject. We shall first pass in review the agents concerned, and the laws which regulate their mutual reactions. We shall then apply our knowledge of these laws to the general explanation of the phenomena of meteorology in their order of importance and natural sequence, and finally afford as complete a view as the very confined limits of this article will allow of those subordinate laws of periodic fluctuations which meteorologists are agreed upon, a knowledge of which, as modified by geographical situation, constitutes the science of climatology; as well as of the combined system of observation and calculation by which this knowledge may be most availably obtained and extended.

Of the Sun as a source of Heat, and of the measure of its direct action. Actinometry.

(7.) The absolute uniformity of the sun's emission of heat is open to considerable doubt. From some recent inquiries by Professor Wolf, it would appear subject to a periodical increase and diminution connected with the abundance and paucity of spots on its disc, a connection surmised by the late Sir William Herschel. That the appearance of such spots is periodical, has been shown by Professor Schwabe. The period assigned is 11.11 years from minimum to minimum, or almost exactly nine periods to each century, commencing at the beginning of the century itself. The last year (1856) has been remarkable for an almost total absence of spots—a fact in perfect agreement with this law. As the planet Jupiter, the largest in our system, revolves about the sun in nearly this time (11.9 y.), it would almost seem as if these singular appearances stood in some connection with electric or magnetic reactions between the sun and planets, the comparatively small discordance of periods being due perhaps to the action of the other planets.[1]

(8.) Independent, however, of any such cause of inequality, the amount of solar heat momentarily received by the earth is subject to a regular annual fluctuation to the extent of one-fifteenth of its mean amount, due to the eccentricity of the earth's orbit—the heat received *in perihelio* (or on the 1st of January) being to that *in aphelio* (July 2d) as 16 to 15. As the sun is vertical over the southern tropic about the former epoch, and over the northern about the latter, it would seem at first sight that the southern hemisphere would receive per annum a larger supply of heat; but the unequal angular velocity of the earth in its orbit, which varies (see ASTRONOMY) in the same precise ratio, effects an exact compensation in this respect by giving a *shorter* duration to a *hotter* summer in the southern hemisphere, and a *longer* to a *cooler* one in the northern.

(9.) The *general* dependence of climate on geographical situation, the high temperature observed at the equator, and the extreme cold at the poles, the annual variations of temperature which accompany the changes of season, as well as the diurnal alternations of heat and cold, are all such obvious consequences of those astronomical arrangements, in consequence of which the sun, at any geographical station, attains a greater or less meridian altitude, and continues a longer or a shorter time above the horizon, as to need no lengthened explanation. The same sunbeam which, at a vertical incidence, acts on a surface equal to its own sectional area, when incident obliquely on the earth (including its atmosphere), is spread over a surface larger in the inverse proportion of radius to the sine of the obliquity. It needs little consideration, then, to perceive that at the poles, where the sun is below the horizon for half the year, and where during the other half it never attains a greater altitude than $23\frac{1}{2}^\circ$, and that only for a short time, its effective warming power on a given horizontal surface must be very far inferior to that which it exercises in the equatorial regions, where its meridional altitude never falls short of $66\frac{1}{2}^\circ$, and where the days and nights are always nearly twelve hours in duration; nor that in intermediate latitudes the increase of its altitude, and the length of the day as it advances along the ecliptic from the winter to the summer solstice, should bring with it that accession of general temperature which we observe.

(10.) This effect of obliquity of incidence is, however, enhanced by another cause. The sun's heat is partially absorbed in passing through the atmosphere, and *that* the more, the greater the mass of air it has to penetrate, or the more obliquely it traverses it. Professor Forbes, reasoning from observations made by himself and M. Kämtz on the Faulhorn in Switzerland, as compared with others at Brienz, 6844 feet lower in level, concludes that 46 per cent. of a vertical sunbeam is absorbed in traversing a *cloudless* atmosphere before reaching the sea level. A series of observations made in Paris by M. Pouillet (in 1837-38) at different zenith distances of the sun, gives only 24 per cent. One-third is probably not too low an estimate. The remaining two-thirds only (or less if the incidence be oblique) are directly effective in heating the earth's surface. The absorbed portion is employed in heating the air throughout its whole extent, and though not ineffective in maintaining the general temperature, acts to that end in a very different manner, as being more immediately transferable from one region to another by the action of the wind.

(11.) From experiments made at the Cape of Good Hope from December 23, 1836, to January 9, 1837, by the writer of this article, it results that the direct heating effect of a vertical sun at the sea level is such as would suffice to melt 0.00754 in. per minute in thickness, from a sheet of ice exposed perpendicularly to its rays. M. Pouillet's conclusions, reduced to a similar form of expression, give 0.00703 in. A mean of the two determinations, 0.007285 in. per minute, may therefore be pretty confidently stated as the measure of the sun's vertical heating power at the sea level in a perfectly cloudless sky. If visible cloud or haziness, even very trifling, be present, the effect is diminished. In a clouded state of the sky nearly the whole of the solar heat is expended in heating the air, and evaporating the clouds.

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[1] While in the act of revising this sheet, we observe in the Royal Society notices for March 12, 1857, a letter from Professor Wolf announcing his discovery of an *annual sub-period* of the spots—a fact strongly corroborative of the view taken in the text.

(12.) Supposing, however, the sky clear, and all the rays of heat equally absorbable (which, however, is not probable), the melting effect per minute of *oblique* sunshine for a zenith distance $= z$ not exceeding 80° on a sheet of ice perpendicularly exposed to it, would be expressed by 0.01093 in. $(\frac{2}{3})^{\text{sec.}\,z.}$, and on a sheet *laid horizontally*, by the same function multiplied by cos. z. This latter effect is the measure of the direct power of sunshine to heat the general surface of the region on which it is incident (abstraction made of the specific nature of that surface). A table, in which the calorific efficacy of a vertical sun is represented by .750, and which gives its diminution for oblique incidences for every fifth degree of altitude, will be found in our article on CLIMATE, vol. vi. p. 776.

(13.) *Actinometry.*—The direct heating power of the sun's rays may be measured in two different ways—statically and dynamically. The statical method consists in equilibrating the heating power of sunshine on some body (as a blackened thermometer) with some external cooling influence which is itself measurable, or which we have reason to believe invariable. It has been usual to suppose this accomplished by simply noting the degree marked by such a blackened thermometer in the sun (exposed till it ceases to rise), in excess of that marked by a similar one in the shade. This is much as if a man should measure his strength by the depth to which he could thrust a pole into the ground, in the absence of any knowledge of its sharpness, or the resistance of the soil. The cooling influences (conduction and radiation) are dependent for their effects on local and temporary circumstances too numerous and too variable to estimate. The measure itself requires to be measured. The objection is palliated but not removed, by enclosing the thermometer in an exhausted glass tube, which eliminates conduction by cutting off the contact of air, and by other methods designed to deaden, or equalize external influences. It is, however, insuperable in principle.

(14.) The dynamical method consists in ascertaining the amount of physical change of a nature susceptible of definite measurement, effected on some object by a given sectional area of sunbeam in a given time, such for instance as the dilatation of a liquid, the melting of ice, or the raising of the temperature of a given quantity of water a certain number of degrees. The first attempts at obtaining such a measure, so far as we are aware, were made by the writer of this article in a tour through Sicily in 1824. A glass vessel full of inked water was exposed alternately 5 m. in sunshine and in shade, the change of temperature being noted by a very delicate thermometer immersed in the liquid, and the solar effect per minute measured by the difference of the minutely changes observed to take place in sunshine and in shade. A similar method was employed in the experiments at the Cape of Good Hope, cited in art. 11; the sun, nearly vertical, being allowed to shine directly on the water. M. Pouillet's "pyrheliometer" is constructed on this principle—a cylindrical body of water, of large diameter in proportion to its height, being enclosed in a metallic vessel of that form with a glass face, which is exposed perpendicularly to the sun. In the "actinometer"[1] a blue liquid (ammonio-sulphate of copper) is enclosed in a glass cylinder, one end of which is closed by a silver screw working in a tight collar, to admit of a small change of capacity when the liquid becomes too much dilated by heat, while the other end is soldered on to a thermometer tube, by which the liquid measures its own dilatation, the cylindrical portion acting as the bulb of the thermometer. The actual temperature of the liquid (on which its dilatability depends) is ascertained by an interior thermometer occupying the axis of the cylinder, and whose stem penetrates the axis of the adjusting screw, and is read off along its exterior prolongation. This instrument being several times alternately exposed for one minute in the sun and shade, and the changes of volume in each case read off on the scale, the differences or sums of the mean changes, according as the action has been in the same or in a contrary direction, gives the dilatation produced by the sunshine alone (freed from the disturbing influences), corresponding to the actual temperature of the liquid, which being reduced by an appropriate table to give the temperature acquired, affords a measure of the effect of a given sectional area of sunbeam in heating a definite volume of liquid. Finally, the result is reduced to "actines," or units of solar radiation, each actine denoting that amount of radiation which would suffice to melt one millionth part of a metre from the thickness of a sheet of ice perpendicularly exposed, in one minute, supposing it wholly absorbed. For the details of the description, the tables to be used for reducing the observations, and the general management of the instrument, our narrow limits compel us to refer the reader to the "Manual of Scientific Enquiry," published by the Board of Admiralty, which contains, moreover, practical directions for making and registering every description of meteorological observation. The portability and facility of use and reduction of this instrument, as well as the consistent results it affords, leave nothing to desire, and afford a perfect measure of solar radiation.

Of the Nature and Constitution of the Atmosphere. Its Pressure, Mass, and Extent.

(15.) We live under what may not improperly be called an ocean of air, which covers the sea and land, and extends far beyond the summits of the highest mountains. Like the sea, this ocean has its currents, which are winds, its waves of vast extent and magnitude, not visible indeed to the eye, but capable of being made so to the intellect by means of the barometer, and its tides, due to the action of the sun and moon. But here the analogy ceases. The air is a permanent gas, incapable of being reduced to the liquid state by any degree of cold or pressure yet applied. As such it is highly and perfectly elastic; condensible by pressure, when confined, into any fraction, however minute, of its ordinary volume, and dilating itself, when relieved, so as to fill any space, however large. Its elastic force, like that of all gases (see PNEUMATICS), is in the direct proportion of its density, its temperature continuing unaltered, but increases, if the temperature be raised at the uniform rate of $\frac{1}{273}$, or 0.00366 of its amount, for every degree centigrade (or 5-9ths of this quantity $=$ 0.002033 for every degree of Fahrenheit's thermometer) of additional heat, and diminishes at the same rate if cooled.

(16.) As the air reposes on the earth, and the whole weight is distributed over the whole globe, each portion (suppose a square inch) of its surface supports the weight of the column of air vertically above it, to whatever height it may extend, and therefore, by the law of reaction, presses upward that column with a force equal to its weight. Hence it follows, that the pressure per square inch, which equilibrates, and therefore measures the elasticity of the air at the earth's surface, must be equal to the weight of such a column. This the barometer enables us to ascertain, at any instant and at any place, by balancing it (see BAROMETER) against that of a column of mercury just sufficient in height to counteract it. It is subject to extensive fluctuations, but observation has shown that the mean or average length of such a column in the latitude of Paris, and at the level of the sea, may be taken at 0.760 met. (French measure) (29.922 in.), the mercury being of the density which it has at the temperature of melting ice, which is 13.596 times that of distilled water at its maximum. If the temperature of the mercury be 62° Fahr., which is the standard temperature of the English metrical system, the dilatation of mercury for 1° Fahr. being almost precisely 1-10,000th of its volume, the corresponding length of the mercurial column is 30.012 in., which is so nearly 30 in. that it is customary for English meteorologists to consider 30 inches as the mean or standard height of the barometer. In all meteorological reductions and discussions, however, wherever the term "*barometric pressure*" is used, it expresses the length of a column of mercury *at the temperature* 0° C. *or* 32° *Fahr.* which balances the aerial pressure.

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[1] First used in the field by the author in 1826, in Cantal, on the Puy de Dome, and at Montpellier.

(17.) The weight of such a column of mercury having a square inch for its base is 14.7304 lbs. avoird., which is therefore the weight of atmosphere incumbent on each square inch of the earth's surface, supposed a perfect sphere. Hence, from the known diameter of the earth (7926 miles), we calculate the total weight of an atmosphere so uniformly covering it at 11.67085 (about $11\frac{2}{3}$ trillions of pounds; so that, making allowance for the space occupied by the land above the sea-level, we may take 11×10^{18} lbs. as an approximate value, which is about 1-188,000,000th part of the mass of the earth itself. Of this, about $99\frac{1}{2}$ per cent. has been ascertained to consist of a mixture of oxygen and nitrogen gases in the proportion of 21 : 79 in volume, or about 23 : 77 in weight. An atomic compound of these gases in the proportion of 2 atoms of nitrogen to 1 of oxygen, would give a ratio of 20 : 80 in volume. Some chemists, therefore, have considered the air as such a compound, and not a mere mixture. But, besides that the deviation of the ratios from each other is beyond the limit of error which chemical analysis tolerates, M. Regnault (Chem. i. 144) has adduced arguments which must be considered decisive against such a conclusion. Still the near approach to an atomic proportion is remarkable. Of the remaining 0.5 per cent, about 0.05 consists of carbonic acid, and 0.45, on an average, of aqueous vapour.

(18.) The specific gravity of dry atmospheric air is to that of mercury (at 32° Fahr., and 0.76 m. pressure), as $1 : 10513\frac{1}{2}$, and a cubic foot of such air weighs 1.29056 oz., so that were the air of that uniform density from the surface upwards, in order to exert the same pressure, it would require to be 26214 feet, or a trifle less than five miles in altitude. This is what is understood by the *height of a homogeneous atmosphere.*

(19.) Such, however, is not the real constitution of the atmosphere. There are mountains higher than this, which yet are covered with perpetual snow, and have clouds above them; and if we consider that each stratum of air, as we ascend from the earth's surface, bears only the weight of those above it, and being therefore less and less pressed, occupies a larger and larger volume in proportion to its weight, we shall perceive that (supposing air infinitely divisible and expansible), there would be no assignable limit to the height of the atmosphere. Theory demonstrates (see PNEUMATICS), that *supposing the temperature uniform* throughout, the density would decrease in geometrical progression as the altitude increases in arithmetical, and assigns for the relation between them the following equation, (in which P, p, represent the densities (measured by the barometric pressures), at the sea level and at the height h, and H the height of a homogeneous atmosphere), viz. $h = \mathrm{H}\,(\mathrm{Log.\ P} - \mathrm{Log.}\ p)$, the logarithms being hyperbolic; or if h and H be expressed in feet, and the hyperbolic reduced to common or tabular logarithms, $h = 60309\,(\mathrm{Log.\ P} - \mathrm{Log.}\ p)$. At the height, then, of 60,000 feet in round numbers, or about $11\frac{1}{2}$ miles, the density of the air on this supposition would be one-tenth of that at the sea level; at 23 miles, one-hundredth; at $33\frac{1}{2}$, one-thousandth, and so on. At an altitude of 103 miles, the density would be reduced to the thousand-millionth part of its superficial amount. Actually (for reasons which will presently appear), the decrease is still more rapid.

(20.) The question, whether or not there be any absolute limit to the atmosphere, has been considered to depend on the view we may take of the intimate constitution of matter. If it consist of ultimate, finite atoms, a limit must at all events occur where the gravity of one atom to the general mass of the earth exceeds the repulsive power exerted on it by the air below it, a question which defies calculation, since we know nothing of the law of force with which the particles of air repel each other, the usual opinion that it is inversely as their distance being quite untenable. If, on the other hand, matter be infinitely divisible, it has been argued by Dr Wollaston that the celestial spaces must be full of attenuated air, and that the sun, planets, and satellites, standing in communication with this general reservoir, would each, in the course of ages, have drawn to itself such a share, that equal densities in their vicinity should correspond to equal forces of gravitation. Calculating on this datum, the sun's atmosphere should have the density of the earth's at the sea level, at about $4\frac{1}{2}$ times *its own radius* above its surface, and Jupiter at above $\frac{8}{11}$. At these distances from the respective luminaries, the rays of light should suffer a deviation by refraction equal to twice our horizontal refraction, or more than a degree, a result directly refuted by observation, which indicates no refraction whatever. This argument, however, takes no account of the effect of centrifugal force. Apart from all considerations of molecular repulsion, it is certain that at about 26,000 miles' distance from the earth's equatorial surface, the centrifugal force would equal gravity, and beyond that distance would exceed it; so that were there no physical cause producing a positive and definite limit, all the air beyond that level must be flirted off into space; and there being no pressure, other air would rise from below to replace it, and share the same fate, so that the whole atmosphere would be drained away, to form a ring like that of Saturn. In fact, however, the excessive tenuity which must, under any hypothesis, be ascribed to the interplanetary air (to express which in fractional parts of its density at the earth's surface would require the denominator to consist of at least 1370 figures), dispenses with giving such reasonings any serious discussion. If, indeed, there were the least ground for believing that atmospheric air could be liquefied by cold of —120° Fahrenheit, the existence of a limit at a very moderate height would follow as a matter of course, as will presently appear. Supposing the law of dilatability to hold good rigorously for all temperatures, the elasticity of air at —273° centigrade would be *nil*. But we have no means of producing this degree of cold, and therefore no experimental examination of the case is possible; and we must therefore be content with the assurance, that at no elevation which can ever be attained by man, or in which animated life could be supported, does the law in question suffer any impeachment; and that at 80 or 90 miles above the earth's surface a vacuum exists, inconceivably more perfect than any which we can produce with our air pumps. At 45 miles the air is already rarified about 25,000 times, at which elevation it would seem, from the duration of twilight, that some feeble reflexion of light still subsists.

(21.) According to Dalton's views respecting the mixture of gases, two or more bodies of this nature mixed together exert no elastic force on each other mutually, though they obstruct and impede each other's free movement. Each *tends* to diffuse itself among the others, and to arrange itself as if the others had no existence, and if left long enough undisturbed would do so. In consequence of this property in a mixed atmosphere, if perfectly quiescent, each gas would constitute a separate and distinct atmosphere, arranged according to the above laws of equilibrium, and each sustaining its quota of the total pressure in the exact proportion of its own volume present in the mixture at the point where the pressure is estimated. But these volumes would be proportionally different at different elevations, the density of the oxygen atmosphere decreasing in a more rapid geometrical progression than that of the nitrogen, and that of the carbonic acid than either. But owing to the obstruction each offers to the free permeation of the others, and to the extreme mobility and continued agitation of the air, the state of equilibrium is never even approached; and experiment has shown that air collected at all elevations above the surface in balloon ascents (in one instance by Gay Lussac, in his memorable ascent in 1804, at the height of 22896 feet), contains these two elements in precisely the same proportions. With the carbonic acid, the case is somewhat different, that gas being subject to local variations consequent on its peculiar uses in the economy of animal and vegetable life; but the differences are so trifling, that for meteorological purposes they may be altogether neglected, and the atmosphere (at least its gaseous portion) regarded as one homogeneous gas.

Of the decrement of Temperature on ascending into the atmosphere, and on the barometric measurement of heights.

(22.) All who have ascended high mountains and all aëronauts are agreed on the fact of a decrease of temperature, which is conspicuously evident from the existence of perpetual snow on elevated summits even in the hottest regions. Respecting the rate of this decrease and its law, much uncertainty still prevails. We possess, it is true, a great accumulation of observations of mountain temperature, both barometrically and trigonometrically determined by De Saussure, Cordier, Ramond, Humboldt, Colonel Sykes, Eschmann, Boblaye, and many others, on the Alps, Pyrenees, Etna, Teneriffe, the Andes and Himalayas, and in Greece; but the results are only loosely accordant, and appear to indicate that the rate of decrease depends in some considerable degree on the season of the year and the local situation of the place of observation. If we assemble the most accordant, and especially those cases where the heights ascended have been considerable, and trigonometrically determined, we find an average decrement of 1° of Fahrenheit's thermometer for every 100 yards of ascent, or 1° per cent. for every 180 yards. The most unexceptionable mode of determining this important element would no doubt be by balloon ascents; but as the heights in such ascents are necessarily determined barometrically, they involve in their calculation (as will presently be shown) the very element in question, and the results deduced from such ascents seem generally to indicate a materially slower rate of decrease. Thus we find, indeed, from Gay Lussac's voyage, as calculated from a decrease of 72·5° Fahr. in ascending 22896 feet, a decrement of 1° in 316 feet, agreeing pretty well with the average above stated. But on the other hand, a mean of four ascents by Mr Green and Mr Rush in the Nassau balloon in 1838 and 1850, to altitudes between 19185 and 20352 feet, gives 485 feet, and a similar mean of four ascents by Mr Welsh in the autumn of 1852 from London, under the direction of the committee of the Kew Observatory, one of which was to the height of 22930 feet, and in which all the observations were conducted with scrupulous precision, and the reductions very scientifically made, afford the result of 386 feet. As a general average deduced, then, from balloon ascents, 400 feet per degree of Fahrenheit would seem to be preferable to 300.

(23.) For the cause, or rather causes, of the general fact of the decrement in question, we have not far to seek. There are several, all probably more or less efficient.

The first is, that in receding from the earth's surface, we are quitting the proximity of a heated body, approaching a region where no such body exists, and interposing more and more of a medium obstructive of heat. If we put any confidence in the theories of Fourrier and Pouillet, the temperature of the interplanetary spaces is probably not higher than −226° Fahr. Consequently, a thermometer exposed at a height where, practically speaking, there is no air, ought at all events not to stand above an arithmetical mean between this and the temperature of the earth's surface below it, that is, −72° at the equator, and −113° at the poles, taking 82° Fahr. and 0° Fahr. as the mean temperatures at those places. Between these two latitudes and levels, then, it would mark, of course, every intermediate degree.

Again, secondly, As the earth's surface receives on the average (art. 10) twice as much solar heat as the air, it is, generally speaking, habitually warmer, and warms the air by constant communication. The heat so imparted is entirely, in the first instance, diffused through the lower strata, only that radiated off going to heat the upper

Thirdly and lastly, there exists a powerful cause, first pointed out by Leslie, of quite a distinct nature, which will need a little more explanation.

(24.) Suppose the atmosphere of equal temperature throughout and at rest. Now let any mass of air at the surface receive an impulse upwards by some external force (not by heating it). It will rise, and in so doing, displace quiescent air above it, which will descend to fill its place, and this process will continue till the upward impulse is extinguished by friction and resistance. In rising, air expands, but as the descending air contracts, *pari passu*, the whole disturbed space when quiet is restored, will be occupied by air as before, and the total pressure will be unaltered. But as regards the distribution of *sensible* heat, a great change will have taken place. The air which has expanded in ascending has absorbed caloric (see HEAT), and grown colder, while that which has contracted in descending has given out just as much, and become hotter. The total heat and the total mass remain unchanged, but the equilibrium of temperature is destroyed. The lower strata have become warmer than the upper, the density adjusts itself accordingly, and the undisturbed column superincumbent on both is supported as before. Precisely the same consequence will result from forcing down by mechanical means (not by cooling) any mass of air from a higher to a lower level. The descending air in condensing becomes heated, while that which ascends to replace it is cooled by its own expansion.

(25.) Now this is no imaginary case. It will be shown hereafter (art. 52) that when aqueous vapour ascends by its levity, it drags air up with it; not by heating it, but by mere mechanical impulse; and thus we see that the mere fact of a circulation of air in the atmosphere, *in so far as that circulation is due to the generation and condensation of vapour, or even to the downward mechanical impulse of the fall of rain or snow*, must of necessity cause a deficiency of *sensible* heat in the higher as compared with the lower regions.[1]

(26.) As regards the law followed by this decrement, little decisive can be said. A uniform rate of decrease, such as that described in art. (26.) as a physical law coextensive with the atmosphere, is not probable, though for heights below 15000 or 20000 feet it is perhaps as exact as any which can be briefly stated in words. Assumed as a basis of calculation, it leads to the following very remarkable relation betwen the height (x) in yards, and the ratio of barometric pressures $\left(\varpi = \frac{p}{\mathrm{P}}\right)$ at the higher and lower levels, viz.—

$$\varpi = \left(\frac{\mathrm{X}}{a}\right)^{5.584}$$

when $a = 180$ yards $(273+\mathrm{T})$, T being the reading of the centigrade thermometer at the lower station, and X the *depression* of the upper station *below* the height a, (reckoned from the lower station) $(\mathrm{X} = a - x)$, which must be considered a limit to the atmosphere, or rather as a limit beyond which the formula is uninterpretable, or, physically speaking, absurd. Nevertheless, within the limits above specified it affords results not very remote from the truth. Thus it gives for Gay Lussac's ascent, calculated on his own data (in which T = 30°.8 C. and $\varpi = 0.42966$), a height of 7678 yards, differing only 46 yards from that assigned by himself. Meteorologists in general, we apprehend, are hardly aware how completely the law of equable decrease is subversive of the received notion of a diminution of pressure in geometric progression upwards from the sea level. This our formula above renders very apparent.

(27.) The law of decrement of temperature is a subject to which great interest is attached, and around which a vast amount of laborious research has accumulated, with a result not unusual in such cases—a great deal of thought and calculation wasted, and no very positive conclusion arrived at. The fact is, the problem has been attacked in the wrong direction. Speculation has been busy in assigning hypothetical laws, either simply tentative, or resting on no solid foundation of physical consideration, to exhibit the relation of the temperature to the height *directly*: to verify which supposes a series of heights and temperatures corresponding to each other to be given by direct observation, the whole series being *comparable*. Now we possess not, and never can possess, any such series; and it is therefore purely and simply groping in the dark to assemble a mass of miscellaneous observation from all quarters, in all climates and seasons, in which insulated decrements of temperature are concluded from mountain ascents; and put them together with the expectation that any intelligible result should emerge. We pass, therefore, without discussion, the theory of M. Biot (Kämtz, ii. 130) which assigns a decrement in geometrical progression for heights in arithmetical, and which sets out with the assumption that the whole heat of the air at any place is due to the extinction of heat radiated or conducted immediately from the earth at that place; or that of Lambert, followed by Baron Zach and Mr Atkinson, in which it is assumed (on a mere general impression that the decrement decreases with the height) that equal decrements of temperature shall correspond to *uniformly increasing increments* of altitude. In fact, no law of decrement, which would not make the density *increase* upwards, would be incompatible with the equilibrium of the strata; and for heights under 10000 feet almost any law and rate which satisfies this condition, and represents the temperatures at the highest and lowest levels correctly, will do so at the intermediate ones. The great defect of all such hypotheses is, that they cannot be fairly tested unless we possessed a scale of heights, trigonometrically determined, up to 20000 or 30000 feet, all in one geographical situation, and readily accessible from the sea level. Balloon ascents, indeed, amply satisfy the latter requirement—but as the heights must be concluded barometrically, they fail to afford what this mode of looking at the subject absolutely requires. A most valuable piece of positive information is, however, afforded by a balloon ascent, viz., that in a given very limited locality, out of the reach of surface inequalities and up-turned currents of heated air, on a given day, and with every facility for obtaining simultaneous observations on the surrounding region, a *definite relation, depending on no hypothesis, but absolutely given by observation, prevails between the temperature and pressure*, as read off at as many different instants, throughout the ascent, as the observer pleases—which relation is capable of being exhibited to the eye with all its capricious incidents by graphical projection in a curve, and of being freed, by a mode of treating such projections which has elsewhere (*Mem. Ast. Soc.* v.) been largely exemplified by the writer of these pages, from the greater part of the errors arising from casual influences or imperfect observation. In the view of the subject we are about to take (which it is something astonishing should have been overlooked by all who have treated of it), this information is all that is necessary for a rigorously exact determination of the heights of the several points of observation themselves, and of the law of decrement which actually subsisted *at the time and place.* By the comparison of such laws at different times and places, it will then be seen whether they are such as really to admit of any uniform or general expression.

(28.) To show this, let p be the barometric pressure, t the temperature (centigrade), and δ the density of the air at any altitude, x and P, T, Δ, those at the sea level, h the height of a homogeneous atmosphere at the temperature 0° C. and H at temperature T. Now if $k = 0.00366$, we shall have by what was shown in art. (15),

$$p = \frac{\delta\,(1+k\,t)}{\Delta\,(1+k\ \mathrm{T})}\mathrm{P}\,; \qquad (1)$$

and since the differential of the pressure $(d\,p)$ is the weight of the column $d\ x$, whose density is δ, $d\,p = \delta.\ d\,x$; (2.) Dividing, then, equation (2) by (1), and observing that $\dfrac{\mathrm{P}}{\Delta\,(1+k\,\mathrm{T})} = h$, we shall have

$$-\,\frac{dp}{p} = \frac{d\,x}{h\,(1+kt)}\,; \qquad (3)$$

If t be known in functions of x, this equation gives at once the relation between the altitude x and the barometric pressure p; and this is the mode in which the analysis of this question has always been conducted. But if put under the form

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[1] If instead of being urged upwards by external impulse, a body of air dilated by heat ascend in consequence of such dilatation, it will rise until its expansion reduces it to the temperature of the surrounding air; but it cannot do so without depressing other air to a lower level, which thus becomes heated, so that in this case also the equilibrium of sensible heat is subverted, though in a somewhat different way.

$$d\left(\frac{x}{h}\right)=-\frac{(1\quad kt)\,dp}{p.},\quad\text{or }\frac{x}{h}=\int-\frac{(1+kt)\,dp}{p};\qquad(4)$$

it becomes available for a different mode of procedure. If the law of temperature, as depending on the *pressure*, be analytically expressible, or if t be an explicit function of p, we have x given at once by integration. But what makes this way of putting the matter peculiarly valuable is, that if this be not the case, but t only given *numerically* by the registered observations of the thermometer, and the reading-off of a graphical projection of them as above described, the integral in question *may be obtained graphically* with quite sufficient precision (practically speaking), and in an infinitely shorter time, than by any system of calculation; so that the determination of the altitudes in balloon ascents is made to depend *on no hypothesis whatever*, but to result purely and absolutely from the series of observed temperatures and pressures in the ascent and descent.

(29.) We have been able to collect no more than nine balloon ascents to sufficient altitudes (which should not be less than 10,000 feet), in which a series of corresponding readings of the two instruments have been taken consecutively enough for discussion, viz., those of Gay Lussac (art. 22), of Messrs Green and Rush in 1838 and 1850 (19185, 20352, 19904, 19440 feet), and of Mr Welsh in 1852 (19510, 19100, 12640, and 22930 feet), these latter leaving nothing to desire in point of instrumental appliances and scientific precision in their use. Plate XVIII. exhibits the graphical projection of the observations registered in each of these ascents, the dots being the points laid down, the continuous curve lines swept among them *liberâ manû*, without reference to any theory, but that one condition without which no general speculation on the subject is possible, viz., that their curvature shall be, generally speaking, similar in character, and have its concavity throughout towards the same side, and the dotted lines analogous curves in which this condition is not adhered to, but in which the most essential peculiarities of each ascent are brought into evidence. Each set of dots is referred to the curve to which it belongs by a light connecting line. The readings-off of these curves are stated in cols. 2, 3 .... 10 of the following table, and are set down *just as they were read from the actual projections used without any subsequent equalization of differences or correction whatever.*

1 $p=$ pressure in inches. $p=$	2 Gay Lussac. Sept. 17, 1804. $t=$	3 Rush, Sept. 4, 1838. $t=$	4 Rush, Sept. 10, 1838. $t=$	5 Rush, June 22, 1850. $t=$	6 Rush, June 29, 1850. $t=$	7 Welsh, Aug. 17, 1852. $t=$	8 Welsh, Aug. 26, 1852. $t=$	9 Welsh, Oct. 21, 1852. $t=$	10 Welsh, Nov. 10, 1852. $t=$	11 Mean of the foregoing $t=$	12 Values of t calculat. from Eqn. Art. 34.
30.5	82°.3 :	66°.4 :	60°.0	73°.2	64°.0 :	73°.0 : :	66°.5 : :	57°.9 :	47°.1 : :	65°.6	
30	81.8	66.0	59.8	72.6	63.4	72.0 :	65.4 :	57.6	46.7 :	65.0	65.0
29	79.7	65.0	59.1	71.0	62.6	69.8	63.3	56.3	45.6	63.6	
28	77.7	63.8	57.8	69.5	61.5	67.4	61.1	55.0	44.1	62.0	62.5
27	75.4	62.6	56.4	68.0	60.0	64.9	58.8	53.5	42.4	60.2	
26	73.0	61.5	54.7	66.2	58.3	62.4	56.2 :	51.3	40.5	58.2	
25	70.6	60.0	52.6	64.4	56.6	59.5	53.3 :	49.4	38.4	56.1	56.3
24	67.8	58.3	50.2	62.3	54.7	56.4	50.5 :	47.0	36.2	53.7	
23	64.7	56.4	47.1	60.0	52.5	53.0	47.6 :	44.2	33.9	51.0	51.0
22	61.6	54.3	43.8	57.6	50.0	49.0	44.4	40.6	31.3	48.1	
21	58.0	52.0	40.4	54.8	47.3	44.8	41.0	36.7	28.7	44.9	
20	54.4	49.1	36.7	51.7	44.4	40.4	37.4	32.5	25.6	41.4	41.0
19	50.2	45.9	33.4	48.6	41.3	35.7	33.7	27.6	22.1	37.6	
18	46.0	42.6	29.5	45.4	37.7	30.8	29.6	22.6	18.4	33.6	33.0
17	41.0	38.5	25.4	41.5	33.3	25.5	25.0	17.6 :	13.8	29.1	
16	35.8	33.5	21.0	37.7	28.3	19.9	19.9	12.0 :	9.4	24.2 :	
15	30.0	28.0	16.4	33.5	23.2	14.0	14.9	6.4 : :	+4.2	19.0 :	19.0
14	23.5	21.9 :	11.0 :	29.0 :	17.2 :	8.0 :	9.6 :	+0.5 : :	—1.5	13.2 :	
13	16.7	15.4 : :	5.4 : :	24.0 : :	11.3 : :	1.4 : :	4.0 : :	—5.5 : :	—7.3	7.3 : :	7.0

Col. 11 contains the means of all the readings in the other columns, and from these a curve (the last of the plate referred to) is laid down which exhibits an average form of the curve, and embodies all the other results. That this proceeding is legitimate will appear from the following consideration:—Suppose t the temperature (or ordinate of any one of the curves) corresponding to the pressure p (the abscissa), and suppose any general relation such as $t=\alpha.\phi(p)+\beta\psi(p)+\&c.$ to subsist, α, β, &c. being parameters peculiar to each curve. Then if there be several such curves in which (corresponding to *the same pressure*) α, β, α', β', α'', β'', &c. are the parameters, and t, t', t'', &c. the ordinates, since $t=\alpha\phi+\beta\psi+\&c.$, $t'=\alpha'\phi+\beta'\psi+\&c.$, we have $\frac{t+t+\&c.}{n}=\frac{a+a'+\&c.}{n}\phi+\frac{\beta+\beta'+\&c.}{n}\psi+\&c.$, which shows that a similar relation subsists between the *mean* of the temperatures and the pressures, provided *mean* values of the parameters are used.

(30.) This essential point premised, we may now observe that the course of all the curves is evidently systematic; that the tendency to fluctuate in one direction in the early part of their course, as marked by the dotted curves in some of them, is contradicted by a similar tendency in the opposite direction in others, and that they agree in speaking a language to the eye which we have to interpret into a formula. Thus a good deal depends on the view we may take of the nature of heat itself and of temperature. Is there an absolute zero? And if so, does matter occupy space in virtue of the presence of heat? If we reply in the affirmative to both these questions, and suppose moreover, empty space absolutely devoid of heat, we must take the extreme lowest thermometer reading, as $t=-\infty$ corresponding to $p=0$. In that case the speculative prolongation of our curve would give it a vertical asymptote at $p=0$, and as its aspect so prolonged bears some general resemblance to a logarithmic curve, we will give that curve a trial. Taking, then, $\log. p = \alpha + \beta t$,[1] (5), we have $\frac{dp}{p} = \beta dt$, and by equation (4) art. (28), $x = h\int -\beta dt(1+kt)$

$$= \beta h\left\{(\mathrm{T}-t) + k\frac{\mathrm{T}^2-t^2}{2}\right\} = \beta h\,(\mathrm{T}-t)\left\{1 + k.\frac{\mathrm{T}+t}{2}\right\}; \quad (6)$$

But by equation (5) we have $\log. \mathrm{P} = \alpha + \beta\,\mathrm{T}$, whence we get $\beta(\mathrm{T}-t) = \log. \mathrm{P} - \log. p$; substituting which in (6) it becomes

$$x = h\,.\,\log.\left(\frac{\mathrm{P}}{p}\right)\left\{1 + k.\frac{\mathrm{T}+t}{2}\right\}; \quad (7)$$

(31.) This is the formula given by Laplace in the tenth book of the *Mécanique Céleste*, abstraction made of two factors in his expression for x, viz. $\left(1 + 0{\cdot}00228\cdot\log.\frac{\mathrm{P}}{p}\right)$ which takes into account the diminution of gravity in receding from the centre of the earth, and $(1 + 0{\cdot}00265\cdot\cos. 2\,\lambda)$, λ being the latitude of the place, which expresses the influence of the centrifugal force arising from the earth's rotation. The value of h, if the logarithms used are the common tabular ones, may be taken at 60309 British feet; if hyperbolic, at 26254 feet. This is the formula (including these factors) now universally adopted for computing heights from barometric observation. Its reduction to numbers is facilitated by tables which are given in the "Annuaire" of the French Board of Longitude, in Galbraith's Barometric Tables (Edin. 1833), and in that very useful collection by Arnold Guyot, published by the Smithsonian Institution, U.S. (Washington, 1852), to which, as containing almost every table a meteorologist can require, we once for all refer our readers. From this formula it appears that, according to the best estimate we can form of the temperature at great elevations, the extreme rarefaction specified in art. (19) as existing at 103 miles, on the supposition there made, would really be found about 11 miles lower, or at about 1-85th part of the earth's diameter above its surface.

(32.) Laplace's investigation of this formula is based on an assumption (avowedly introduced by him for the sole purpose of simplifying his analysis) of a variation of temperature with altitude which amounts to supposing equal decrements of temperature to correspond to increments of height, *decreasing* progressively in arithmetical progression. This is in fact the law of decrement which would result from our equation (6). It is therefore precisely the reverse of that of Lambert, Zach, and Atkinson, and, we may add, not in accordance with the general impression among meteorologists (in which, however, we do not participate), that the decrease is *slower* the higher we ascend. It is somewhat singular that Laplace does not appear to have noticed the logarithmic relation (5) which his hypothesis implies between the temperature and pressure; and still more so (and we are surprised that the remark should not have occurred either to Laplace himself, or to any of those who have used his formula) that his expression *is identical with that which would result from assigning to the whole atmosphere a uniform temperature, the mean of those actually observed at the higher and lower levels.*

(33.) When we come to examine our curve of decrement more particularly, however, it becomes evident that it is *not* a logarithmic curve, but a most undeniable parabola. The errors in the former case are systematic, and far beyond bearable limits. Supposing the curves to agree at the 15th and 30th inch of p, the errors are at 13, 17, 20, 23, 27, and 30.5 inches respectively $+2{\cdot}2°$, $-1{\cdot}8°$, $-3{\cdot}3°$, $-4{\cdot}2°$, $-2{\cdot}2°$, and $+1{\cdot}2°$. The logarithmic curve, therefore, is not in satisfactory accordance with the average course of nature as collected from these observations.

(34.) If we take for Fahrenheit's scale $\alpha = -87°$, $\beta = +9{\cdot}0667$, and $\gamma = -0{\cdot}1333$, or for the centigrade $\alpha = -66{\cdot}1111$, $\beta = +5{\cdot}0370$, and $\gamma = -0{\cdot}0741$, we shall find the numbers in col. 11 to be perfectly well represented by the equation $t = \alpha + \beta\,p + \gamma\,p^2$, substituting which in equation (4), integrating from P and T to p and t, eliminating γ by the equation $\mathrm{T} - t = \beta\,(\mathrm{P} - p) + \gamma\,(\mathrm{P}^2 - p^2)$, taking 60309 ft. for the value of h (as adapted for the use of *common* logarithms), putting for k its value 0·00366, and using the centigrade values of α and β, we shall find

$$x = h\left\{(1 + 0{\cdot}00366\,\alpha)\log.\frac{\mathrm{P}}{p} + 0{\cdot}000795\left\{(\mathrm{T}-t) + \beta\,(\mathrm{P}-p)\right\}\right\}; \quad (10)$$

(35.) To apply this formula to any proposed ascent, the readings of the instruments having been graphically projected, two extreme and one intermediate pair of corresponding values of t and p are to be fixed upon, and thence by resolving the three simple equations of the form $\alpha + p\,.\,\beta + p^2.\,\gamma = t$ which these afford, the values of α and β are obtained, which may then be substituted in (10), and the value of x determined. As an example we shall take Mr Welsh's ascent of Nov. 10, which gives $\mathrm{P} = 29{\cdot}972$, $p = 12{\cdot}240$; $\mathrm{T} = 46°{\cdot}7$ F. $= 8°{\cdot}16$ C.; $t = -11°{\cdot}3$ F. $= -24°{\cdot}06$ C.; $\alpha = -94°{\cdot}804$ F. $= -70°{\cdot}44$ C.; and $\beta = +8°{\cdot}4848$ F. $= +4°{\cdot}7136$ C., and executing the calculation we obtain $x = 22983$ feet, which corrected (by the factors in art. 31) for latitude and decrease of gravity, finally gives $x = 23027$ feet, being 97 feet in excess of the height assigned by Mr Welsh from Laplace's formula; by which it appears that, whatever be the objections to which the law of temperature implied in that formula may be liable, it may still be safely used even for such altitudes.

(36.) If $p = 0$, or so nearly such as would be the case in ascending some 25 or 30 miles, $t = \alpha$, which is therefore the temperature a thermometer would mark exposed to the total joint radiation of the earth and air from beneath, and to that into space from above. If then we call S the temperature of space *beyond the influence of terrestrial radiation*, we have, at least approximatively, $\alpha = \frac{1}{2}(\mathrm{T} + \mathrm{S})$. Now we have seen that in our mean curve $\alpha = -87°$ F. and $\mathrm{T} = +65°$ F., and that in Mr Welsh's last ascent $\alpha = -95$, $\mathrm{T} = +49$. Both agree in giving $\mathrm{S} = -239°$ F. Hence we may conclude generally, that taking for S this value, α may be at once assumed as $= \frac{\mathrm{T}}{2} - 119\frac{1}{2}°$ F. At the equator, then, the limiting temperature of the atmosphere would average $-77\frac{1}{2}°$ F., and at the poles about $-119\frac{1}{2}°$ F., with a range of temperature from the surface of $161\frac{1}{2}°$ in the former case and $119\frac{1}{2}°$ in the latter.

Of land and water as recipients and communicants of heat.

(37.) Of the solar heat which actually reaches the surface of the globe, that which falls on water penetrates it to some moderate depth and is absorbed internally, while that which is incident on land is wholly absorbed superficially, or within a very minute thickness. Water, moreover, is eminently a non-conductor of heat, so that once received into its substance it is only diffusible by agitation; and since this, however violent at the surface of the ocean, diminishes rapidly with the depth, the ultimate communication of heat downwards to any considerable depth is a very slow process. By far the greater portion of the daily supply of heat to water then may be said to float within a moderate depth of the surface, forming a kind of reservoir of heat. On the other hand, water is a *good radiant,* and as such is continually both day and night giving off radiant caloric, which is absorbed in traversing the air, and thereby tends to raise the temperature of the latter medium. It is a property of caloric radiant from bodies heated below incandescence to be eminently absorbable by transparent media. (See HEAT.) Hence it is most probable that much of the heat so radiated off is detained in the lower strata of the air. Meanwhile a balance is struck in the water itself of the quantities received and parted with, by the preponderance of one or the other of which it gains or loses in average temperature on the 24 hours. Thus, in the warm season, when days are long and nights short, the general temperature of the sea is slowly rising above its annual average, and *vice versa* in the opposite season. Below a certain depth, however, the temperature of the ocean would appear to be determined by other causes, and to be very little dependent on its superficial amount or fluctuations. It results from the observations of Kotzebue, Beechy, and Sir James C. Ross, as a general fact ascertained by thermometric soundings, that the deep sea water below a certain level, determined by the latitude, is of invariable temperature throughout the globe, and that a very low one; the calculations of Lenz, founded on Kotzebue's results, giving 36° F., and those of Ross 39°.5 (which last is the temperature at which pure water attains its maximum of density). The depth at which the fixed temperature is attained is about 7200 feet at the equator, diminishing to lat. 56° on either side of that line, where it attains the surface, and the sea (superficial currents apart) is of equal temperature at all depths. Thence, again, the upper surface of this uniform substratum descends, and at 70° of latitude has already attained a depth of 4500 feet. Thus the ocean is divided into three great regions; two polar basins in which the surface temperature is below 39°, and one medial zone above it, attaining 82° at the equator, and at the poles of course the freezing point of sea water. It is within these respective regions only, then, that superficial currents can act as transporters of *meteorological* temperature.

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[1] t here expresses centigrade degrees, the same form applying equally to either mode of expression.

(38.) The habitudes of dry land with relation to incident heat are very different. There is no mobility of parts, and the communication of heat downwards is therefore entirely a process of conduction. But what is most influential, is the fact that the absorption is performed strictly on the exposed surface, which therefore in the instant of absorption fixes upon itself within a very minute depth all the heat which, falling on water, would in the same instant be disseminated through many feet or yards of its substance. The mere superficial film, then, becomes much more heated, and, since it is a law of radiation that its intensity increases rapidly with the temperature of the radiant surface, it radiates out on the very instant a much larger fraction of the total incident heat than in the case of water, besides imparting to the air by contact-communication a proportionally greater amount. In water the absorbed heat is for the most part withdrawn from the radiant action, enveloped and husbanded. In dry land it is instantly and wholly exposed to such action in its most intense form. It is no uncommon thing in dry and light (*i. e.* badly conducting) soils, in hot climates, to find a superficial temperature of 120°, 140° F., and even more. We have ourselves observed it at 159° F. at the Cape of Good Hope. In the arid regions of Australia, Captain Sturt reports that a lucifer match dropped on the ground takes fire. The surface water of the equatorial seas is scarcely ever known to range higher than 83° in the day, and 82° in the night.

(39.) That portion of the heat which enters the soil is conducted downwards, and so long as the surface is gaining in temperature a wave of heat is continuously propagated downwards into the earth. When the surface, however, by the decline of the sun, begins to lose heat, this ceases, and (the radiation still continuing) what may be called a wave of cold (less comparative heat) begins to be propagated, and so on alternately during the day and night. These waves as they run on spread forwards *and backwards*, and so by degrees neutralize and destroy each other. Thus the diurnal fluctuations of temperature beneath the surface grow continually less as the depth increases; the rate of diminution depending on the "conductibility" of the soil. In ordinary soils the difference between the diurnal and nocturnal extremes becomes imperceptible at four feet below the surface. (Quetelet, *Mem. Acad. Brux.*, 1836). In like manner, the general increase of heat due to the summer season, and of cold during winter, are propagated in similar but larger and feebler annual waves, which in their turn neutralize each other at more considerable depths, and become imperceptible at 40 or 50 feet. Professor Forbes has shown in an elaborate memoir on this subject (*Trans. R. S. Edin.*, xvi.) that at depths varying from 57 to 99 feet, according to the nature of the soil, the annual variation does not exceed 0°.01 C.

(40.) The absorption of incident heat *as solar heat*, and its radiation outwards *as terrestrial heat* (*i. e.* heat of a much more absorbable nature) by the solid surface, depends very much on the nature of its substance; but if the ground be covered with vegetation, *the whole* of the *incident heat* is returned back either by radiation or contact-communication to the air; and the soil receives no heat where so covered, otherwise than circuitously through the medium of heated air. All these causes acting together produce a vast difference as respects the temperature *of the air* in regions of the globe covered by the ocean and those occupied by dry land. In the former its fluctuations, both diurnal and annual, are confined within very much narrower limits than in the latter; and this contrast, which theory indicates, is confirmed by universal observation, as the expression of the distinction between an *insular* and a *continental* climate, or that of a small island remote from all other land and of the central regions of an extensive continent. If there be one general feature in meteorology more prominent than another it is the uniformity of temperature over great bodies of water, as compared to that under similar exposures to the sun on land.

(41.) *Terrestrial Radiation.*—The theory of radiant heat promulgated by Prevost, which all experimental inquiry into the subject has tended to confirm, lays it down as a principle, that a mutual interchange of heat is continually taking place between all bodies freely exposed to view of each other, the hotter radiating more than the colder in the ratio of some function increasing with the temperature. The experiments of Dulong and Petit on the radiation of bodies in vacuo, have shown that this function, within the limits of their experiments, is of the exponential form, or in other words, that the force of radiation in vacuo increases in geometrical progression as the excess of temperature of the radiant body above that of its envelope increases in arithmetical.[1] Hence, when a hot body is placed in presence of bodies, some colder some hotter than itself, an equilibrium will rapidly be established, in which its momentary gains and losses of heat to and fro among them all will balance each other, and its temperature will thenceforward be unchanged.

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[1] There must be some natural limit to such a law. Radiation in absolute vacuity *cannot be infinite.*

(42.) Such will be the case if the body be completely surrounded or enclosed by others. But if only partially so, if there be an opening out into perfectly free space, through which rays of heat can escape, and from which none are returned, heat will constantly flow out from such a system, and the body will be maintained at a temperature lower than that of such partial envelope, and the more so the larger the *angular area* of the opening.

(43.) If it were certain that the vacuum, or ætherial medium in which the planets move, and which conveys light, had absolutely *no temperature* of its own capable of being imparted to matter, and if the air were perfectly transcalescent and incapable of radiation from its own particles, or from those of impurities floating in it, a thermometer placed a very small distance from the ground, with an unobstructed view of the sky, would receive from the hemisphere above it no heat but that radiated from the stars and moon; or (putting the moon out of the question, as it is almost certain that no portion of her heat escapes absorption in the air), none bearing a greater ratio to that it would receive from the sun, than the light of a starlight night to direct sunshine, which cannot exceed that of 1 to 100000000. It may therefore be regarded as *nil*.

(44.) The mean temperature of the earth remaining unchanged, it necessarily follows that it emits by radiation *from* and *through* the surface of its atmosphere, on an average, the exact amount of heat it receives from the sun, *i.e.*, as much as would melt 0·01093 in. in thickness of ice per minute over the area of one of its great circles, or one-fourth of this thickness (0·00273 in.) over its whole surface (art. 11, 12), which is equivalent to 135-960ths of that quantity, or 0·000374 in. depth of water per minute (or 1-40th in. per hour), condensed from its dew point. Taking this as the measure of the total average radiation, one-third of it, or 1-120th in., may be taken as radiated off from the atmosphere without ever reaching the earth, and the remaining two-thirds (1-60th in.), may be considered as got rid of by radiation, direct or indirect, from the surface of the earth. In complete absence of any means of estimating the ratio of these portions, we may suppose the latter to be one-half of 1-60th or 1-120th in. Let us now consider the manner in which this part of the process takes place, supposing a clear sky to prevail.

(45.) Conduction through the soil is a very slow process, radiation a very rapid one. So soon, then, as the sun has sunk so low as not to counteract the earth's radiation, the immediate surface begins to part with its heat, at first, of course, slowly, but as night advances more rapidly, and at length much faster than it can percolate from the interior to supply the waste. The surface, therefore, becomes greatly chilled, and a wave of cold (to use the mode of expression adopted in art. 39) is propagated downwards, neutralizing and destroying the heat-wave rising to meet it, a process which goes on leisurely, and takes its own time. Meanwhile the chilled surface now borrows heat from the air also, to supply its waste, 1st, by contact-communication; 2d, by downward radiation; *and, 3d, by condensation of vapour when the temperature of the surface-air is reduced to the dew point*, and thus attains that state of equilibrium which the circumstances admit of. The process is in fact in every respect the converse of that described (art. 38), by which heat penetrates the soil, the immediate surface exhibiting in both cases the most sudden and violent effect of the acting causes.

(46.) The most consecutive series of experiments and observations we possess on terrestrial radiation, are those of Professor Daniell, Captain Sabine, and more recently Mr Glaisher, the author of a very elaborate memoir on the subject (*Phil. Trans.*, 1847). Our limits will only permit us to mention some of the more prominent results obtained. The maximum of terrestrial radiation takes place when a perfect calm and cloudless sky prevail during a long night, in a level country. Under these circumstances, there is nothing to disturb the air immediately resting on the soil, so as to replace the air cooled by contact with the chilled surface by warmer air from above; and if a series of thermometers be exposed at various heights above the surface, that which is just not in contact will be found to mark several degrees lower than the general temperature of the air, and the others at greater altitudes, will stand progressively higher up, to about 10 or 12 feet, the difference, however, above 4 feet being very trifling.

(47.) The depression of the thermometer exposed to radiation in contact with any horizontal surface is greater as the radiating power of the substance of which that surface consists is greater, and as its power of conducting heat is less. The greatest depression observed by Mr Glaisher below a thermometer freely suspended at 12 feet above the ground, was no less than 28°.5 Fahr.! the lower thermometer being placed on raw cotton wool on long grass. The relative depressing powers of this and other supporting substances, assigned by him from a mean of all his observations, are given below; long grass being taken as a standard.

Hare Skin,	1316	Charcoal Powder	776
Rabbit Skin,	1240	Jet-black Lambs' Wool,	741
Raw White Wool,	1222	Sheet Zinc,	681
Flax,	1186	White Tin,	667
Raw Silk,	1107	Snow,	657
Unwrought White Cotton Wool,	1085	Sheet-Iron,	642
Long Grass,	1000	Paper,	614
Lamp-black Powder,	961	Slate,	573
Flannel,	871	Garden Mould,	472
Glass,	864	River Sand,	454
Sheet Copper,	839	Stone,	390
Coloured Lambs' Wool,	832	Brick,	372
Whiting-powder,	827	Gravel,	288

(48.) When a thermometer is exposed with its bulb in the focus of a concave silver hemisphere [1] or paraboloid, highly polished both internally and externally, and deep enough, when exposed with the concavity upwards, to cut off from the thermometer all view of the earth, and as it were to continue the sky beneath it, it can only receive heat by condensation and radiation from the air, and from the condensation of moisture. A thermometer so exposed under a clear sky, and shaded from direct sunshine, always marks several degrees below the temperature of the air, and its depression affords a rude measure (of the statical kind, and open to all the objections to which that kind of measure is open.—See art. 13) of the facility for the escape of heat by radiation afforded under the circumstances of exposure. As compared with exposure on any of the supporting substances above enumerated, the depressing power of such a reflection by Mr Glaisher's experiments appears to be 888, that of long grass being 1000, which is almost identical with that of the glass of which the bulb is formed. If the axis of such a reflector be directed to a cloud, or to any terrestrial object, the thermometer immediately rises, even should that object be the summit of a snow-covered mountain (as we had ourselves occasion to observe on April 18, 1824, from the roof of the observatory at Turin, the snowy range of the Alps affording an excellent object for trial). If directed to a cloud, the height of the cloud is not indifferent—Mr Glaisher's observations clearly showing that the higher the cloud the greater the radiation upward, whether estimated by the reflector, or by the depression of a thermometer laid on grass. Thus, in nights uniformly and totally cloudy, the mean height of the clouds being respectively 1900, 2800, and 3700 feet (which his peculiar situation enabled him to ascertain), the depressions were found to average 1°.6, 2°.5, 3°.9, clearly indicating the lower temperature of the higher clouds.

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[1] The figure is absolutely of no importance. A paraboloid is generally used, for no reason that we can perceive but to increase the cost.

(49.) As an instance of the effect of terrestrial radiation applied to a practical purpose, may be mentioned the manufacture of ice in the East Indies. The process, as described by Mr Williams (*Phil. Tr.*, vol. lxxxiii. p. 56) practised in Benares on an immense scale, consists in exposing shallow porous earthen pans on straw in a level area, divided into compartments four or five feet square. The pans are filled in the afternoon; and the temperature being much reduced by evaporation before night, the freezing process is completed by radiation at night. In this way Mr Williams has often seen ice $1\frac{1}{4}$ inch in thickness produced in December, January, and February, the thermometer at $5\frac{1}{2}$ feet above the ground, marking from 41° to 46° Fahr. In a night of 12 hours, it may be remarked, the mean emission of heat from the earth's surface, taken as two-thirds of the total mean radiation, would suffice for the conversion of 480×0·00273 or 1·31 in. into ice. (art. 44.) So that there can be no necessity to recur to other causes than radiation (as has been done by some) for a full account of the effect observed.

(50.) *Of the evaporation and condensation of water, and the dilatation of air, as elements of power in Meteorological Dynamics.*—Water, freely exposed to the air, evaporates at all temperatures, even *when in the state of snow or ice.* The rapidity of evaporation is, however, much increased by warmth. Thus, in a calm atmosphere, under the ordinary pressure, Dalton found that when, from a certain surface, the evaporation from boiling water proceeded at the rate of 40 grs. per minute, it was 20 grs. at a temperature of 180° Fahr, 13 grs. at 164°, 10 grs. at 152°, and so on. *Cæteris paribus*, in dry air the rapidity of evaporation is proportional to the elastic force with which the generated vapour tends to escape from the evaporating surface; *i. e.*, to the tension of vapour due to the temperature of that surface (See Evaporation). If the air be already moist, evaporation is proportionally retarded, the force of escape being the difference between the elastic tensions of the generated vapour and of that already existing in the air. Under a low atmospheric pressure, also, it is far more rapid than under a high one, owing to the comparative absence of obstruction to the diffusion of vapour by the aerial particles—vapour being subject to the same laws of diffusion and non-reciprocity of pressure as other gases, and indeed, *while maintained in the vaporous state*, to all the other laws of gaseous statics and dynamics (See Heat). Owing to the same reason, evaporation is accelerated by wind blowing over the evaporating surface, which removes the generated vapour as fast as it is produced, and dispenses with the slower process of diffusion upwards. *Cæteris paribus*, moreover, the amount of water evaporated is proportional to the surface exposed to air. It is much greater, therefore, from rough and porous solid substances kept wetted (as, for instance, from moist soil or from vegetation wetted by rain), than from the surface of water itself; and from the latter, when agitated by winds or dashed in spray, than when tranquil.

(51.) Evaporation never takes place without the abstraction of heat from the evaporating surface. Every grain of water evaporated carries off with it sufficient heat to raise 960 grains, 1° Fahr., to supply which, that quantity of the residual water must have been cooled 1°. This heat, however, is *latent*, *i.e.*, does not appear as *temperature* in the vapour produced, which is no warmer than the surface from which it emanates. On condensation, however, the absorbed heat is given out again; and thus aqueous vapour becomes an agent in the transfer of heat, in its latent state, from one part of the globe, or from one region of the atmosphere to another, just as a moving body transfers the impetus which created its velocity to the place where it encounters an obstacle.

(52.) Vapour introduced into the air acts as a moving power in two distinct ways. 1*st*, By a simple addition of volume. The tension of the vapour is added to the elastic force of the air, according to Dalton's law, and increases by the same amount the total power of the mixture to support pressure. Were the specific gravity of vapour the same with that of air, the effect of its introduction would be simply one of distension. It would tend to relieve itself by lateral diffusion, or removal of obstructing air; and if prevented from so doing, would simply heave up the incumbent aerial column in struggling to diffuse itself, and so increase its total vertical altitude. 2*d*, But a far more efficacious motive power originates in the less specific gravity of the vapour of water than of air of the same temperature (0·6235 : 1). It is the lightest of all known "vapours," and, with exception of hydrogen and ammonia, the lightest of gases. In consequence, as soon as generated, it tends to rise in the air by its buoyancy, and in so doing, carries up with it much of the air with which it is intermixed, disengaging itself no doubt from it, in its upward progress, to become entangled, however, with fresh particles, which again it carries upward, to abandon them for others. In this way, not only is its upward diffusion far more rapid than its horizontal, but in its struggle upwards it tends to produce an ascensional movement in the air itself, and thus (as we shall presently see) to act as a powerful agent in the production of wind.

(53.) Whenever vapour comes in contact with any body, or arrives at any locality whose temperature is lower than that due to its tension, a portion of it condenses into water, or, it may be, into ice. In so doing it gives out again its latent heat, which is communicated to the condensing body, raising its temperature, or else is disseminated throughout the region, together with the condensed particles. If the condensation be into water, the heat thus reappearing as temperature is precisely the same in amount as that taken up in evaporating the same quantity of vapour from water, or 960° Fahr.; if into ice, the additional amount of 135°, which is that which becomes latent on the conversion of ice into water, is set free. If the condensation take place at the surface of the earth, the result is dew or hoar-frost, according as the surface is above or below the freezing-point; if aloft in the air, the result is a cloud or mist, or, if abundant, rain, snow, or hail. But in every case the condensation of vapour is accompanied with a mitigation of cold *at the point where it actually takes place.* The same is true of the freezing of water, however contrary to ordinary notions. Were it not for this, our winters would be intolerable.

(54.) It is clear, moreover, that the generation of vapour, under any extensive region, *more rapidly than it is carried off* by diffusion or otherwise, must be attended with an increase of barometric pressure, since the total weight of the atmosphere vertically over any region must be supported by the total area of surface, and equally so that its condensation, *provided the condensed water* be abstracted from the atmosphere, must lead to a diminution of pressure. The contrary will happen if the vapour generated be carried off as fast as produced by such a general upheaving of the aerial strata over any region as shall subvert their equilibrium, and cause them to overflow, upwards and laterally. In such a case, since air also will be carried off bodily from the region, and be replaced by vapour, the mean specific gravity of the whole aerial column, and its total weight, will be diminished, and the barometric pressure lowered. This takes place on a most extensive scale over the intertropical seas. The temperature of the surface water in them is habitually very elevated (from 78° at the tropics to 83° at the equator), and varies very little by the vicissitudes of season, or the alternation of day and night. A steady and copious evaporation is therefore continually going on. Vapour, carrying with it air, is constantly thrown up beyond the levels of equilibrium, where it flows over and spreads itself out over the upper regions of higher latitudes. The immediate consequence is a habitual deficiency of barometric pressure at the sea-level on the equatorial, as compared with that on the extra-tropical seas. In a voyage to the Cape of Good Hope in 1833-34, the writer of these pages found this decrease from the tropics to the equator, on either side, to amount to 0·24 in.

(55.) The dilatation of the air itself by heat, whether communicated to it from the earth, or radiated directly into it from the sun, acts in a somewhat different manner. Air is dilated only by about one-tenth of its volume by 50° Fahr. increase of temperature, so that, unless locally and violently heated, its effect in producing bodily uprushing currents is comparatively less than that of the introduction of vapour into its mass. When heated over large tracts, it acts rather by increased elasticity to upheave the superincumbent strata, and, by bulging them upwards, to destroy their equilibrium, and cause the upper atmosphere to flow over on less heated regions. The general effect, however, is similar; and as the sun cannot generate vapour without at the same time heating the air, it is impossible to separate their dynamical effects. Whether the air go forth from its place *proprio motu*, or be jostled out of it by the introduction of a lighter medium, the local relief of pressure is equally produced.

(56.) *Of the winds.*—Among the proximate agents in meteorology, the winds hold the first place. To their agency is owing the subversion of what Humboldt has termed the *solar climate* of the world (or that which would exist were the atmosphere motionless), and the production of its *real climate*. This they effect in two ways, viz., 1st, *Directly*, by transferring into regions remote from their origin the heated air and aqueous vapour (charged with latent heat) which the sun's direct action generates; and, 2dly, *Indirectly*, by causing currents in the ocean, which convey to one locality the surface water heated in another. In both ways they effect a constant circulation, both of heat and moisture, the two great elements of climate, which cannot therefore be understood till we know something of the habitual force and direction of these great aerial movements, considered on an extensive scale.

(57.) A very small difference of atmospheric pressures, as a moving power, suffices to generate a considerable wind. Calculating from a formula given by D. Bernouilli to express the velocity of a gas issuing through an orifice in a vessel in which it is compressed into surrounding air of less elasticity, it appears that, to generate in atmospheric air, velocities of efflux equal respectively to 10, 20, 30; 60, 90, 120; and 150 feet per second (or of 7, 14, 21; 41, 61, 82; and 92 miles per hour), would require corresponding effective differences of pressure of 0·006 in., 0·010 in., 0·016 in., 0·06 in., 0·14 in., 0·25 in., and 0·41 in., which may be taken as the velocities of wind in a gentle air, a light breeze, a good sailing breeze, a gale, a great storm, a tempest, and a hurricane producing universal desolation, sweeping away buildings, and tearing up trees. The corresponding pressures of the wind per square foot on a plane surface, perpendicularly opposed to it, are respectively in pounds 0·2, 0·9, 1·9; 7·5, 16·7, 30·7; 37·9. It must be borne in mind, however, that for such pressures to produce the velocities ascribed to them, they must be supposed to act unmitigated by any graduation, which is never the case in nature, the transition from a higher to a lower pressure at stations remote from each other being always extremely gradual, so that barometric elevations and depressions to a much larger extent may and do exist without giving rise to great winds. It is only when sensible differences subsist between the pressures at places near each other that violent phenomena arise.

(58.) We have seen that the immediate effect of the application of heat to any region is to generate an ascensional movement in the incumbent atmosphere, a bodily overflowing of its material above, and a relief of barometrical pressure below. The air of the cooler surrounding region not being so relieved (but rather the contrary, owing to the increase of weight poured on it from above), will be driven in by the difference of hydrostatic pressures so arising, and thus originate two distinct winds, an upper one setting *outward* from the heated region, a lower *inward*. If the region heated be a limited one, these currents will radiate from and to it as a centre; if a linear tract, or a whole zone of the globe, such as the generally heated intertropical region, they will assume the character of two sheets of air setting inwards on both sides below, uniting and flowing vertically upwards along the medial line, and again separating aloft, and taking on a reversed movement.

(59.) In this account of the production of wind, however, no account is taken of the earth's rotation on its axis, which modifies all the phenomena, and gives their peculiar character to all the great aerial currents which prevail over the globe. The first clear perception and announcement of this cause, as affording an explanation of the trade winds (otherwise inexplicable), is due to Hadley (*Phil. Tr.*, 1735), and affords a beautiful demonstration of that great astronomical principle as a physical fact. To form a right estimate of its importance, it is only necessary to observe, that of all the winds which occur over the whole earth, one-half at least, more probably two-thirds, of the average momentum is nothing else than force given out by the globe in its rotation in the trade currents, and in the act of reabsorption or resumption by it from the anti-trades.

(60.) Since the earth revolves on an axis passing through its poles from west to east, each point in its surface has a rotatory velocity eastward proportional to the radius of its circle of latitude, and any body of air relatively quiescent on that point will have the same. Conceive now such a body to be urged by any impulse in the direction of a meridian towards the equator. Since such impulse communicates to it no increase of easterly velocity, it will find itself, at each point of its progress, continually more and more deficient in this element of movement, and will lag behind the swifter surface below it, or drag upon it with a relative westerly tendency. In other words, it will no longer be a direct north or south wind, but, relatively to the surface over which it is moving, will assume continually more and more the character of a north-easterly or south-easterly one, according as it approaches the equator from the north or south.

(61.) Meanwhile, however, the earth is continually acting on the air by friction, and communicating to it rotatory velocity. As it approaches the equator, in whose vicinity the diurnal circles increase more slowly, the relative westerly tendency is continually less and less reinforced by the cause which produced it, and the counteraction arising from friction acquires energy, till, on arriving near the equator, the wind loses its easterly character altogether; while the northern and southern currents, here meeting and opposing, mutually destroy each other, producing a calm; and become deflected upwards, to form an ascensional current, replacing the air abstracted. The result, then, is the formation of two great tropical belts, in the northern of which a north-easterly, and in the southern a south-easterly wind prevails, while the winds in the equatorial belt which separates them, are comparatively feeble and free from any steady prevalence of easterly character. This is the general description of the trade winds as actually observed.

(62.) A precisely contrary set of re-actions takes place on the upheaved or displaced equatorial air. In flowing over to regain its level, it commences its course relatively in a meridional direction, but really with the full amount of easterly velocity which the earth's equator has; and since this, as it proceeds north or southwards, is in excess of what would suffice to keep it on the same meridian, it continually deviates to the westward; and when it again returns to the earth in its circulation, which it does on both sides beyond the tropics, it does so with a powerful westward tendency, and the more, as in its course it has been less under the influence of surface friction, owing to the elevated region in which it has travelled. It thus restores to the mass of the earth the momentum abstracted by it in the former phase of the cycle. We have here the origin of the SW. and westerly gales, so prevalent in our latitudes, and of the almost universally westerly winds in the northern and southern extra-tropical seas. The existence of an upper current, opposite in direction to the under, is a matter of frequent observation, as shown by the courses of a lower and higher stratum of clouds.

(63.) Were the whole globe covered with water, and the sun always in the equinoctial, the system of the trades and anti-trades (for so the compensating westerly winds may conveniently be designated) would be perfectly symmetrical about the equator, as their medial line. Two causes tend to derange this symmetry, viz.:—1*st*, The movement of the sun in declination, which carries it alternately away from the equator to 23½° on either side; and 2*d*, The existence and peculiar form of the continents.

(64.) Suppose the sun at the northern tropic. At that time, the region beneath the southern being 47° from the circle of vertical sunshine, will be receiving little more than half its maximum of solar heat (art. 12), and the circle of 47° latitude will be receiving as much heat as the equator itself, or more, the days being longer. If this state of things were permanent, the neutral line would shift from the equator to the northern tropic, carrying the whole system of the trades with it. But the sun approaches the tropic gradually, and does not remain there, but returns to the equator; and as, moreover, the general temperature of the ocean follows very slowly the action of its rays (art. 40), these effects cannot be fully wrought out, or nearly so, and the utmost that could arise would be a very moderate northerly transfer of the medial line, and with it, of the inner and outer limits of the trades; and as the reverse effects will of course arise when the sun gets into south declination, the result altogether will issue in a periodical annual oscillation of the wind system to and fro on either side the equator; the maximum excursions falling later in the year than the precise epochs of the solstice, on the general principle *that cumulative effects necessarily attain their maximum later in point of time than their causes.*

(65.) This is very nearly an accurate account of the real state of things in the Pacific Ocean, whose vast extent brings it within the general scope of our hypothesis, and in which the north-eastern trade extends from about 2° to 23° north latitude, in its mean situation, and the south-eastern from about 3° to 21° south latitude. Between them lies an equatorial belt of about 5° in breadth, of such habitual calm as to have given a name to the ocean itself. The annual oscillation is confined within very moderate limits.

(66.) In the Atlantic the disturbing influence of the continents is very sensibly felt. The great mass of Africa, and especially of its sandy and burning deserts, lies considerably north of the equator. These become intensely heated, and their temperature *follows the sun* much more closely than that of the sea. There can be no doubt that the medial line of the trades crosses Africa considerably to the north of the equator, nor that the annual oscillation of the northern trades at least is very great, and the influence extends to the neighbouring Atlantic. In this ocean the equatorial limit of the north-east trade shifts with the season from 5° 15′ to 11° N. lat., and that of the south from about 2° to 3° 15′ N., so that the medial line lies always a little north of the equator.

(67.) It is in the Indian seas, however, and especially in the vicinity of the great Asiatic continent, that the disturbing influence of the land is most clearly exhibited, issuing in a complete reversal of the north-east trade during a considerable portion of the year, and the production of monsoons, *i.e.*, of winds which blow half the year in one, and the other half in the contrary direction. When the sun is south of the equinoctial, it being the cold season in those continental regions, the regular trade winds prevail throughout those seas, and what is called the north-east monsoon is in fact no other than the undisturbed north-east trade wind. But where the sun has north latitude, and especially about the northern solstice, it is vertical over a very large region of Arabia, Hindostan, Bengal, Burmah, and Cochin, which become, of course, intensely heated. Under these circumstances, besides the permanent line of maximum temperature in the equatorial sea, there is developed another more intense and less regular line of the same nature, under or near the northern tropic, towards which, and not towards the equator, a large proportion of the intermediate air is drawn. Receiving thence a *northern* impulse, and that impulse carrying it into a region of less rotatory velocity than that which it has left, it assumes a relative south-west direction, and is called the south-west monsoon. Meanwhile, south of the equator, the south-east trade continues to prevail from May to October over all that part of the Indian Ocean which is not skirted with large tracts of land to the south; but where this is the case, as in the Java seas, as far as New Guinea, which are skirted to the south by the great Australian continent, we have again a double maximum, and the phenomenon of a NW. monsoon taking the place of the SE. trade. Our limits will not allow us to pursue this subject into details, for which we must refer to Dove's Meteorological Researches, Kämtz's Meteorology, and Horsburgh's India Directory. The setting in of the monsoon is generally accompanied by deluges of rain and thunder storms of excessive violence.

(68.) *Sea and land winds.*—The uniformity of temperature over a surface of sea, compared with that over land, gives rise to winds alternately setting to and from the land, at those seasons when it is powerfully heated in the day time, while at night its temperature sinks to an equality, or even sometimes below, that of the sea surrounding it. As the hottest and coldest hours of the day are about 2 P.M. and a little before sunrise, the winds in question necessarily attain their greatest power at somewhat later epochs in the day.

(69.) *Dove's law of rotation of the wind.*—It is not, however, merely in the great system of aerial movements which affect the whole atmosphere, that the influence of the earth's rotation is felt. Even very limited local movements are modified by it. It is a remark as old as Lord Bacon (*de Ventis*, 1600), and since confirmed by Mariotte in France, Sturm in Germany, Toaldo in Italy, and many other writers both in Europe and North America, that the wind has a decidedly preponderating tendency to veer round the compass according to the sun's motion, *i.e.*, to pass from N. through NE., E., SE., to south, and so on round in the same direction through west to north; that it often makes a complete circuit in that direction, or more than one in succession (occupying sometimes many days in so doing), but that it rarely veers, and very rarely or never makes a complete circuit in the contrary direction. M. Dove in his "*Meteorologische Untersuchungen*," was the first to show that this tendency is a direct consequence of the cause above mentioned.

(70.) Suppose that at any station in north latitude, after a calm, the air over and around the place, for some considerable distance, to receive an impulse in the direction of a meridian, carrying it towards the equator. The first air which passes over the station, coming from its immediate neighbourhood, has the same rotatory velocity as the station, and therefore passes it as *a north wind.* But the movement continuing, that which arrives subsequently having set out from a continually higher and higher latitude, arrives with continually less and less rotatory velocity, and therefore in its passage over the station, will relatively decline more and more to the east, and pass as a north-east wind. If now the southward movement relax, and at length cease, the relative motion from the east will continue for a while, till destroyed by friction, and the wind will for the moment have become a direct east wind. Now, suppose a contrary impulse given, or that the mass of air begins to travel again northward, the east wind will evidently begin to be deflected towards the north, and will become a south-east wind. As the northward movement continues, the fresh arrivals will bring with them an excess of rotatory velocity, or a tendency to blow relatively *from the west*, and will thus first neutralize the easterly character, changing the wind from SE. to S., and finally overcome it, passing into a south-west wind. If, then, the other oscillation take place, and the mass of air begin again to travel southward, the wind, by the very same reasoning, will gradually change to west, then by NW. to N., and finally come round again to the NE. It is obvious that for a station in south latitude, the conditions being reversed, a contrary law of rotation ought to prevail. Observations in south latitude are in great measure wanting by which to test this theory. In north, as we have seen, it is found conformable to fact.

(71.) In the tropical regions, where the superficial air always flows towards the equator, no such oscillatory movement northwards and southwards, as is above supposed, takes place. Where monsoons exist, there is but one such oscillation annually, and accordingly the wind makes one annual circuit; but in the temperate zones beyond the trades, as casual circumstances determine, equatorial and polar tendencies alternately preponderate, and every oscillatory movement so impressed is thus converted into a circulation in a fixed direction.

(72.) *Cyclones.*—The West Indian seas, those about Mauritius, and the China seas, are infested with *hurricanes*, or storms of wind, of excessive violence, productive of frightful devastation both on land and on sea, and which, in addition to the interest which such scourges must always command, have of late come to possess a peculiar one in the eyes of meteorologists, on account of the remarkable features in their history brought to light by the laborious researches of Professor Redfield, Colonel Reid, and Mr Piddington. By a collection of the log-books of ships which have encountered such storms, and the comparison of the recorded directions of the wind, at different periods of their progress on land, in regions devastated by them, the following general facts respecting them have been established, viz., 1st, That in any such hurricane, the movement of the air (regarding its whole extent) is vorticose. They are in fact whirlwinds, though often of vast magnitude, the diameters of some of them, which have been already traced, exceeding 500 miles, though for the most part not more than 200 or 300. Hence the name given to them of cyclones. 2d, The centre of the vortex is not fixed, but travels leisurely enough (from 2 to 30 miles per hour), along certain tracts. In the West Indies they are confined to a pretty definite area, their usual course being in a parabolic curve, having some point near Bermuda for its focus—originating in the Gulf of Florida—and running along the coasts of the United States, following generally the course of the Gulf Stream, and sweeping across the Atlantic, occasionally visiting our island. In the southern Indian seas, according to Mr Piddington (*Sailor's Handbook*), they follow also parabolic curves, the vertices of which often sweep round the isles of Mauritius, Rodriguez, and Bourbon, and whose average focus is a point about 25° S. lat. and 70° E. long. Along the arcs of these parabolas, in both regions, the initial movement of the centre of the storm is westward, so that the movement of the cyclone in its parabolic orbit is contrary to that of the wind in the cyclone itself. 3d, In cyclones which occur in the northern hemisphere, the rotation of the air is invariably in the contrary direction of the hands of a watch laid face uppermost ↶ ; in those of the southern hemisphere the reverse, ↷. 4th, They originate between the tropics, and run outwards from the equator towards the poles. But *on the equator itself they never occur.* 5th, They are announced by a rapid fall of the barometer, the depression being greatest in the centre (sometimes amounting to two inches!) 6th, The wind is most violent in the neighbourhood of the centre of the cyclone, but as the centre itself passes over any spot, a momentary calm is observed, the wind immediately recommencing in the reverse direction to what it had the instant before (a necessary consequence of the vorticose motion).

(73.) A complete account of all these characters is afforded by Hadley's principle, as developed by Dove in his "Law of Rotation," and applied to this specific class of aerial movements by Professor Taylor. Suppose (in the northern hemisphere), that owing to the application of local heat, a tendency in the air over some extensive locality C, to ascend in a vertical column should arise; to supply the place of the air so ascending, an indraught from all the surrounding region will commence. Let the equal lines N*n*, 1-1, 2-2, 3-3, E*e*, &c. (fig. 1) represent the forces and directions of currents drawn in from equidistant points, situated to the N., NNE., NE., ENE., East, &c.; then, were the earth at rest, these currents would all press towards C with equal force, and the lines N*n*, &c., would be terminated by concentric circles, and a mere vertical ascending current without gyration would result. But the earth revolving from W. to E., take to the westwards of *n*, *na* to N*n* as the difference of the rotatory velocities at N, *n* to the velocity of the indraught; join N*n*, which will then represent the *relative* force and direction of the current setting in from N; and a similar construction being made at every other point, the system of relative currents will be that represented by the arrows N*a*, 1 *b*, 2 *c*, 3 *d*, E *e*, &c. And it needs but a bare inspection of the figure to perceive that such a system terminating in an ascensional movement over the tract C can be no other than a vortex or spiral eddy in the direction of the internal curved arrow, *i.e.*, in a direction contrary to the motion of the hands of a watch laid face upwards. In the southern hemisphere it will be the reverse, as will appear on drawing the figure.

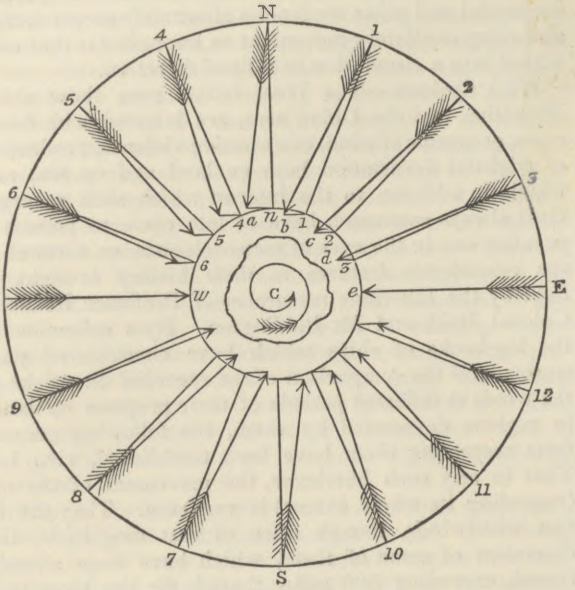

Fig. 1.

(74.) It is also obvious that the force of the vortex so arising must be in proportion to the strength of its efficient causes. In high latitudes there is a deficiency of solar heat and aqueous evaporation to produce a sufficiently powerful ascending current. On the other hand, on the equator, with abundant heat, the other efficient cause, viz., a difference of diurnal rotatory velocity, is absent.

(75.) *Atmospheric waves.*—The atmosphere, like the ocean, has its waves, which are rendered sensible by the increase or diminution of barometric pressure, as the crest or the trough of the wave passes over the place of observation. They are, however, on a much vaster scale than those of the sea, as might be expected, from the greater mobility of the medium, and the extent of surface over which their existing causes act simultaneously. But they are distinguished from the latter by features of a peculiar kind, which depend on two causes, viz., 1st, The varying density of the air from the earth upwards; and, 2d, The fact that the disturbances in which they originate are not (as in the case of the sea-waves) merely superficial, but extend through the whole depth of the atmosphere, and are most powerful at the ground level.

(76.) A very good general notion may be formed of the peculiar modification of waves which depend on a decreasing density of the medium in which they are excited, by pouring into a large glass vessel fluids of different densities which do not mix, and which have different colours. An undulatory movement impressed on such a system disappears very speedily from the surface of the uppermost fluid, but continues long after to agitate the lower strata; and moreover the latter, while possessing the inertia which belong to their *entire* densities, but the preponderant weight which corresponds only to their *differences* of density from those above them, are less controlled by gravity in proportion, and their excursions above and below their planes of equilibrium are therefore vastly exaggerated. Again, if there are several such strata, which is easily managed by carefully pouring, one over the other, several fluids (even if *miscible*, provided actual *mixture* be avoided), their undulations are far from maintaining any parallelism or correspondence; and it will be found practicable to propagate in them waves of independent origin, and differing in direction, mutually reacting on each other. The aerial waves are, besides, exaggerated by the elasticity of the medium, the portion thrown up, *ipso facto*, dilating itself, and therefore swelling into a higher convexity than it would assume if inelastic.

(77.) As the attraction of the sun and moon tend to produce an elliptic distortion in the spherical outline of the ocean (whose vertex follows the luminaries), and which thus becomes converted into a great circulating tide-wave, with two maxima and two minima in the luni-solar day; so the heat of the sun producing a far more considerable elevation of the level lines, and a far greater disturbance of equilibrium in the aerial hemisphere beneath it, while the nightly chill on the other side acts *in a contrary sense* on the opposite hemisphere, a similar, but much more considerable circulating wave, or *heat-tide*, is generated, following the sun (as all cumulative and periodical effects follow their causes) at a certain interval, but which differs from the sea-tide wave in having only one elevation and one depression of the barometric column, and in having a mean solar day for its period. Of this, more hereafter. The gravitation-tide, depending on the joint attraction of the sun and moon, gives rise to no greater difference of level in the aerial strata than what the same causes produce in the ocean itself, viz., about six feet. Their effect on the barometer would amount at the maximum to less than 1-130th of an inch.

(78.) Were the sun constantly vertical over the equator (exactly as in the astronomical theory of the tides), no annual fluctuation would arise; but as the point of maximum heat oscillates from tropic to tropic, an annual transfer of air from hemisphere to hemisphere takes place, producing a fluctuation analogous to the menstrual inequality of the tides arising from the moon's change of declination—only as there is more time given for this cause to work out its effect, and the obstructing causes are comparatively feeble, the extent of the annual variation in the barometric pressure bears a much greater ratio to the diurnal than in the analogous case: and for the same reason, as in the diurnal fluctuation, the wave which causes it is single, not double crested.

(79.) It is not with these fluctuations, however, that we are now concerned. They will be considered under another head. The atmospheric waves here considered are those which originate, not from the general movement of the whole body of the atmosphere, but from internal displacements, the result of winds diverted from their course, or of great local disturbances of temperature, due to a concurrence of circumstances which may be termed casual, forasmuch as we cannot trace their laws. Such waves have been traced by comparing hourly observations of the barometer made by numerous observers, on certain days determined by preconcerted arrangement, in distant places, the progress of the waves, their general direction, their height, and velocity, being concluded from the rise and fall of the barometer as noted in each. Thus, to cite some instances, it has been found that on the 21st of September 1836, by observations made at Markree, Limerick, Halifax, Oxford, London, Brussels, Hanover, Geneva, Turin, Gibraltar, and Cadiz, a wave having a barometric depth of 0.2 in., was ascertained to have passed over the British Isles and the west of Europe, having its crest nearly in the direction NNE. or SSW., and the direction of its progress nearly from WNW. to ESE. The half breadth of this wave, which occupied nearly 26 hours in its passage, extended from Oxford to near Halle in Würtemberg (about 540 miles). Its velocity of advance was about 26 miles per hour. Again, on the 21st of December 1837, a very well defined wave travelled in a direction from 10° north of W. to 10° south of E., at the rate of 18·62 miles per hour. The total depth of this wave from crest to trough was measured by fully $\frac{3}{4}$ inch of barometric pressure, so that the level strata must have fluctuated through a vertical height of at least 700 feet. The area over which this wave was traced, is marked by fifteen stations of observation, extending from Markree in Ireland, to Parma in Italy.—(*Brit. Ass. Rep.* 1843.)

(80.) It would appear from the researches of Mr Birt, that a very remarkable wave of this kind (to which he has given the name of "the great November wave") passes annually over these islands and the adjacent regions (embracing probably the whole of Europe and the seas on its north-west coasts in its range), the crest extending in a direction from NE. to SW., the direction of progress (at right angles to this or) from NW. to SE., the velocity about nineteen miles per hour. Both the breadth and depth of this wave are on a vast scale. The whole wave occupies about fourteen days in its transit, the crest passing over London about the middle of November, so that its total breadth cannot be less than 6000 miles, while the extent of barometric elevation from its trough to its crest seldom falls short of an inch, and occasionally amounts to double that quantity. What is no less remarkable, there is a certain region (in which London is included), over which the rise and fall of the barometer during the transit of the wave exhibit a considerable resemblance, so that a section of it, in the direction of its advance, would be a symmetrical curve, the middle crest being preceded and followed at about five days' interval by two lower ones, and the beginning and the end marked by deep depressions. The researches of M. Le Verrier leave no doubt that the great Crimean storm of the 14th November 1854, of disastrous memory, was part and parcel of this phenomenon.

(81.) *Anemometry.*—The wind, regarded as a meteorological element to be measured and recorded, differs from other elements, inasmuch as it offers two distinct objects of measurement, viz., its direction and velocity; three, indeed, since the quantity of air passing over a given place of observation varies as the velocity and density jointly. This, however, is a nicety into which meteorologists have not yet thought it worth while to go, being content to regard the number of miles travelled over by the wind in a given direction as expressing the material transfer of the air in that direction. In fact, as different and often opposing currents co-exist at different levels, it would be a useless refinement to do so. The direction and velocity, however, are essential features. The former is readily determined by a well-constructed vane, erected high enough to be out of the reach of eddies, and either read off on a divided circle to degrees of deviation from the meridional direction, or so mechanically arranged as to register itself at every instant. The velocity may be measured (or self-recorded) in several different ways. As, for instance, first, by causing the wind to act perpendicularly (as in Osler's anemometer) against a square foot of surface, so as to drive back a spring of known elasticity, the extent of compression determining the number of pounds which equilibrate the momentum per square foot, and which (like the direction) may be self-recorded at every instant. Secondly, by causing it to drive round the fans of a light vane, presented always perpendicular to its direction, and registering the number of its turns by means of an endless screw and wheelwork, as in Whewell's construction (C. U. Phil. Tr. vi.; improved by Dr. Robinson, Mem. R. I. Acad. xxii.), which has the advantage of giving not merely the momentary velocity, but the total or integral amount of space run over, or the transfer of air per day, per hour, or per minute, as may be required.

(82.) Since the whole of the air in the region surrounding the place of observation participates in the movement so recorded, and must be considered as transferred bodily at each instant with a motion equal and parallel, the particle which was first over the spot will describe a curve whose elementary arc and direction are determined, and may therefore be traced, either by hand or by a self-acting movement in the mechanism of the anemometer on any scale. Suppose (fig. 2) A p q r B to be the trace of one day's movement, A S the direction of the meridian, p, q, r, the points attained at stated hours, t_1, t_2, &c. and let Q_1, Q_2, Q_3, &c. be the angles p A P, $q\,p\,a$, $r\,q\,b$, &c. or the directions of the wind, reckoned round the compass from the north, eastwards, and v_1, v_2, &c. its velocities; then since $p\,\mathrm{P} = v \,.\, \sin.\, \theta$, $\mathrm{AP} = v \,.\, \cos.\, \theta$; if dt be the element of the time, we shall have $\mathrm{AS} = \int v dt \,.\, \cos.\, \theta$, and $\mathrm{BS} = \int v dt \,.\, \sin.\, \theta$, from $t = 0$ to $t = 24$ h. in strictness; and approximately—

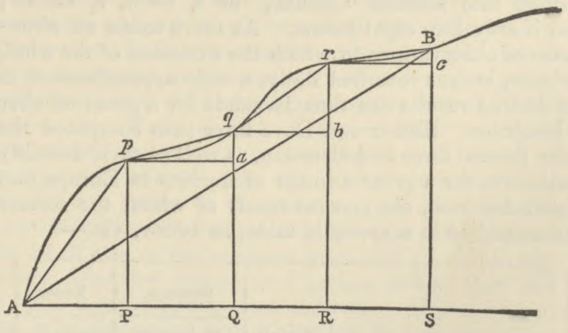

Fig. 2.

$$\mathrm{BS} = v_1 \,.\, \sin.\, \theta_1 + v_2 \,.\, \sin.\, \theta_2 + \&c. = \mathrm{A}$$

$$\mathrm{AS} = v_1 \,.\, \cos.\, \theta_1 + v_2 \,.\, \cos.\, \theta_2 + \&c. = \mathrm{B}$$

So that if AB be joined, AB representing the mean movement during the twenty-four hours, if AB = V, and BAS = φ, we shall have

$$V = \sqrt{A^2 + B^2}; \text{ tan. } \varphi = \frac{A}{V},$$

whence the mean velocity and direction, during the twenty-four hours, may be calculated from a series of registered numbers, or from the measurement of AB and BS on the self-registered trace.

(83.) If AB, BC, CD, DE, &c., represent the mean diurnal movements during a week, month, or year (fig. 3), so, by a similar system of calculation, may the mean weekly, monthly, or annual direction and velocity be computed. Hitherto it has not been possible to obtain the necessary data for any considerable number of stations, the instruments required being both costly and comparatively of recent construction. But no class of observations is calculated to afford more insight into the sequence of meteorological changes; and they cannot be too earnestly recommended to general attention. Meanwhile, in the absence of all information as to the velocity of the wind, it has been the practice to assume *all winds as of equal force*, or rather that the force of winds may be regarded, on the average, as measured by the frequency of their occurrence. The formula given by Lambert for the average direction and force of the wind, is founded on this supposition (a most misleading one), and consists in substituting for v_1, v_2, &c., in the general values of A and B above given, the numbers n_1, n_2, and in which the winds N., NNE., NE., &c., making angles $\theta_1 = 0$, $\theta_2 = 22^\circ\frac{1}{2}$, $\theta_3 = 45^\circ$, &c., supposing the circumference divided into sixteen "points;" or $\theta_1 = 0$, $\theta_2 = 45^\circ$, &c., if only into eight points. As there exists an abundance of observations in which the direction of the wind, *per vane*, is thus recorded daily, a rude approximation to the desired results can thus be made for a great number of localities. Kämtz and Dove have thus computed the mean annual force and direction, as well as their monthly variations, for a great number of stations in Europe and North America, the general result of which the former has embodied in a synoptic table, as below, viz.—

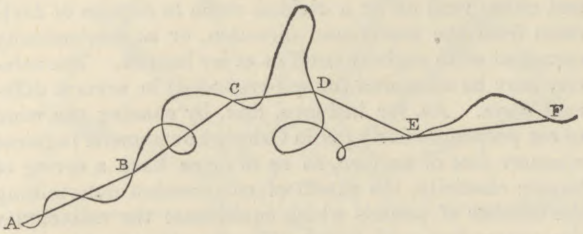

Fig. 3.

	Direction.	Force.
England	S. 66° W.	0.198
France and Holland	S. 88 W.	0.135
Germany	S. 76 W.	0.177
Denmark	S. 62 W.	0.170
Sweden	S. 77 W.	0.228
Eastern Europe	N. 87 W.	0.167
Northern part of United States	S. 86 W.	0.182

in which the numbers under the column headed Force express the values of V in the formula so modified.

(84.) *Oceanic Currents.*—The winds act indirectly as distributors of heat and moisture, by producing currents in the ocean. Were there a free communication round the globe, at or about its equator, the continuous action of the trades could not fail to establish a westerly circulation of the equatorial waters with little deviation to the north or south; and were the whole globe covered with water, the compensating SW. and NW. winds beyond the tropics would produce two extra-tropical easterly currents, surrounding the globe, and separated from the equatorial one by zones of still water, a lively picture in short of what is most probably the state of the planet Jupiter (the rotatory velocity of whose equator is 26 times greater than the earth's) as concluded from the appearance of its belts.

(85.) The continent of America, however, which presents an unbroken barrier as far as the 55th degree of south latitude, effectually prevents the equatorial current from making a complete circuit round the globe, its passage round Cape Horn being barred by the contrary southern compensating current. Its passage round the Cape of Good Hope, also, is materially impeded, though not prevented, by a similar cause, so that in the Atlantic two vast eddies are formed, in the southern of which the water, deflected along the Brazilian coast till it meets the opposite current at Cape Horn, joins that current, and is swept eastward with it. In the northern it is thrown upon the north-east coast of South America, through the Caribbean Sea, obliquely into the hollow of the Gulf of Mexico, where it is suddenly and violently deflected to the north-west, and issues in what is called the Gulf Stream, to which, as a very powerful agent in determining our own climate, we must devote some small space, referring the reader for further details on the subject of currents to our article HYDROGRAPHY, and to the chart of Oceanic Currents by Captain Beechy, in the *Admiralty Manual of Scientific Enquiry*, p. 106.

(86.) The Gulf Stream, where it quits the Gulf of Florida, has a velocity of from three to five miles per hour (varying with the season), a breadth of only a few miles, and a temperature of 83°. Thence it follows the coast of America to about the 36th degree of latitude, where it still possesses a temperature of 76° Fahr., and where it quits the coast about Cape Fear, and encircling the Azores, spreads itself in wide diverging streams over the basin of the Atlantic, between the coasts of America and Spain, forming a vast eddy, overgrown with the "sargasso" or Gulf weed. The main stream, however, continues to run north-westward, directed full towards the British Islands, to about the 46th parallel, in the 40th degree of west longitude, where its force is much weakened by subdivision. The surface water, however, continues to flow onwards in the same direction, and its presence on our western shores is evidenced by the warm vapours the south-west winds waft from above it, and by tropical plants and seeds thrown ashore on the west coast of Ireland, on the Hebrides, and even on Norway. Were the isthmus of Panama broken through, there is no doubt that the whole climate of our islands would undergo a most notable deterioration.

(87.) *Of the precipitation of vapour, and the formation of dew, fogs, clouds and rain, &c.*—Air and vapour, according to the views of Deluc (first distinctly announced in a very remarkable paper, *Phil. Tr.* 1792, p. 400), and the theory of the independent elasticity of gases in general, announced by Dalton in 1801, form two distinct and in great measure independent atmospheres; the one permanent in material and constant in quantity—the other in a continual state of destruction and renovation. Were the temperature of all regions of the globe alike, no precipitation of vapour in the form of rain or snow would ever take place. A certain definite amount of vapour once generated and diffused, would remain as a permanent constituent of the atmosphere, and each aerial stratum would exist in a state of habitual exact saturation, so that no further evaporation would take place from a moist surface at whatever level exposed. But owing to the equatorial heat, the polar cold, and the great system of circulation established by the winds, the atmosphere is converted into a great distilling apparatus, and the vapour raised in warmer regions is continually being precipitated in colder, according to laws which we are now to trace.

(88.) The most immediate, though assuredly not the most obvious result of this state of things, is a general fact avouched (like the cold of the higher regions) by all mountain travellers and all aeronauts, viz.—The habitual *hygrometric* or *relative dryness of those regions* IN CLEAR WEATHER. This is shown by very ordinary but very demonstrative facts. Thus Deluc remarked that the head of his walking stick always fell off in high mountain ascents, from the shrinking of the wood. We have seen that were there never any rain, &c., each stratum of the air would be in an exact state of saturation, and no evaporation would be possible from a moist surface at any level. "But[1] every act of precipitation, no matter how produced, unsettles this state of things and withdraws from the total mass of air some portion of its entire amount of vapour. As such precipitations, therefore, are constantly going on in some place or other, the atmosphere, as a mass, though incumbent on a wet and evaporating surface, is necessarily always deficient in moisture; and for the very same reason, every superior stratum is relatively deficient in comparison with that immediately beneath it, from which its supply is derived. In point of ultimate causation, then, there is a constant drain on the aqueous contents of the atmosphere, arising from changes of temperature. This drain extends to all its strata; but while the lower renew their losses from a surface hygrometrically *wet*, the upper draw *their* supply from sources more and more deficient in moisture." What the equatorial depression of the barometer at the sea level then is to the system of winds, such is the habitual hygrometric dryness of the air above the clouds to that of rains—at once an indication of a process in progress, and an efficient agent in continuing it. Wherever such relative dryness exists, vapour, by its own expansive *nisus*, is in the act of transfer *in an invisible state* from one atmospheric region to another, and the rapidity of that transfer is proportional, *cœteris paribus*, to the degree of dryness, as the velocity of a river at any point is to the inclination of its surface to the horizon. This by no means supposes a universally prevalent deficiency of vaporous tension. Complete saturation must exist at the points of evaporation and deposition, but at intermediate ones any amount of irregularity may prevail according to local circumstances.

(89.) *Hygrometry.*—To obtain a measure of this important element is the object of *hygrometry*, which consists in determining by instrumental means the absolute quantity of water existing, as vapour, in a given volume (suppose a cubic foot) of air, under any circumstances of temperature and pressure, and thence, from the known specific gravity of vapour, deducing its elastic force or tension. For the ways in which this may be accomplished, and for a description of the instruments used, the reader is referred to our article on HYGROMETRY. The method now adopted in preference to all others, as the most simple and convenient in practice, and leading to results which a very severe examination has proved to be quite satisfactory, is the simultaneous observation of the wet and dry thermometer. The formula of reduction, as it results from Dr Apjohn's elaborate investigations, is as follows:—Let t, t' be the respective readings of the *wet* and *dry* thermometers (in degrees Fahrenheit), h the barometric pressure in inches, f the elastic force of saturated vapour at the temperature t, and F its elastic force at the "Dew-point," or at that temperature which the air ought to have, so as to be exactly saturated with the quantity of vapour it actually contains. Then will

$$F = f - \frac{t'-t}{80} \cdot \frac{h}{30}; \ (a) \qquad \text{or, } F = f - \frac{t'-t}{96} \cdot \frac{h}{30}; \ (b)$$

the equation (a) or (b) being used according as t, the reading of the wet thermometer, is above or below 32°. f is found from a table of the elastic force of saturated vapour (see STEAM) at different temperatures, which will also be found in the *Admiralty Manual of Scientific Enquiry*, p. 321; and F being calculated from the above expression, the dew-point may be had from the same table, used reversely, *i.e.*, entering the table with F and finding the corresponding temperature. F known, the weight of water per cubic foot is found by multiplying the weight of a cubic foot of dry air at 30 inches (563·2124 grs.) by the specific gravity of steam for elasticity F, *i.e.*, by F × 0·6235, or by the formula F × 35·166. Copious tables for facilitating the whole process have been published by Mr Glaisher, (*Hygrom. Tables*, Lond. R. and J. E. Taylor. 1847.)

(90.) If the temperature of any given space containing vapour be higher than its dew-point, water exposed in it will evaporate. The air it contains is then said to be *relatively* more or less dry, or (in reference to the old chemical theory of solution advanced by Hutton, the language of which being convenient, is retained, though the theory is exploded), under-saturated. If lower, some portion of the vapour will begin to be precipitated, and this precipitate assumes various forms, according to the circumstances under which a sufficiently low temperature is produced.

(91.) I. *Dew.*—When the mass of moist air is simply brought into contact with a cold body, the result is *dew*, which is deposited in minute globules of water on the body, or if the temperature of the latter be below the freezing-point, ice or *hoar-frost*. The nature of these phenomena was, up to a late period, strangely misconceived,—the effect, by a mistake very common in meteorology, being put for the cause, the dew being regarded as *producing* the chill accompanying it, instead of the reverse. Dr Wells, in his "Essay on Dew"—a little work which deserves to be considered as a model of experimental inquiry—was the first to place in a clear light the true nature of the process. The chief facts to be accounted for are these:—1st. Dew (as distinguished from small rain or the moisture produced by visible fog) is never deposited except on a surface colder than the air. 2d. It is never deposited in cloudy weather; and so strict is its connection with *a clear sky*, that its deposition is immediately suspended whenever any considerable cloud passes the zenith of the place of observation. 3d. It is never *copiously* deposited in a place screened or sheltered from *a clear view of the sky*, even if the screen be of very thin material, such as muslin or paper suspended over it. 4th. It is most copiously deposited on all such bodies as are *good radiants and bad conductors of heat*, such as grass, paper, glass, wool, &c., but little or not at all on *bad radiants*, such as polished metals, which are also *good conductors*. And, lastly, it is never deposited if there be much wind. All these circumstances, as Dr Wells has shown, point to the escape of heat from the bodies exposed by *radiation out into space*, or into the upper and colder regions of the air, faster than it can be restored by counter-radiation or by *conduction* from contact with the warm air or with solid substances—wind acting in this respect with great efficacy, by continually renewing the air in contact. Hoar-frost differs only from dew by being frozen in the moment of deposition, and therefore accreting in crystalline spiculæ.

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[1] Edinburgh Review, 1848.

(92.) II. *Mist or Fog.* If a table of vapour tension, or the formula from which such a table is calculated, viz.

$$\text{Tab. Log.}\left(\frac{p}{30}\right) = -0.0085412197.t - 0.0000208109.t^2 + 0.000000058.t^3$$

where p is the elastic force of saturated vapour, corresponding to a temperature of 212°—t Fahr. (Biot, *Tr. de Phys.* i. 278), be projected into a curve, (fig. 4), taking t for an abscissa, and p for an ordinate, it will be found to have the form P D Q convex in every part towards its axis or asymptote A B. Hence, if between any two dew-point temperatures, A M, A N, an arithmetical mean A B be taken, and P, Q, the ends of the ordinates joined, B E will express the arithmetical mean of the extreme ordinates, or of the elasticities at the two temperatures, and B D (less than B E) that corresponding to their mean. Hence it is evident, that if two equal volumes of air, saturated at temperatures t and t' be mixed, since the mixture will have the mean temperature, water must be precipitated, the corresponding vapour tension being less than the mean. The form in which the moisture so precipitated first appears, will necessarily be that of very minutely divided particles, which, however, having the refractive power of water, reflect and refract light as such, and appear therefore as a mist, fog, or cloud of greater or less density and opacity, according to the amount precipitated in a given volume. It is a favourite dogma with many meteorologists, that the particles so precipitated assume the form, not of drops, but of hollow spheres or bubbles. De Saussure states, that he has seen such floating before his eyes in clouds and fogs on the Alps, and the dusty appearance of the vapour floating over a cup of coffee in the sunshine is adduced in proof. The strongest argument in their favour, however (for there is great room for optical illusion in such matters), is that adduced by Kratzenstein, that the sun striking on a cloud or fog produces no rainbow, which it ought to do were the water collected in spherical *drops*. This argument does not admit of a ready answer; but the difficulty, on the other hand, of conceiving any possible mode in which such bubbles can be formed, disposes us to believe that the extreme minuteness of the globules may perhaps be found to afford one, their diameters being probably of an order comparable with the breadths of the luminiferous undulations.

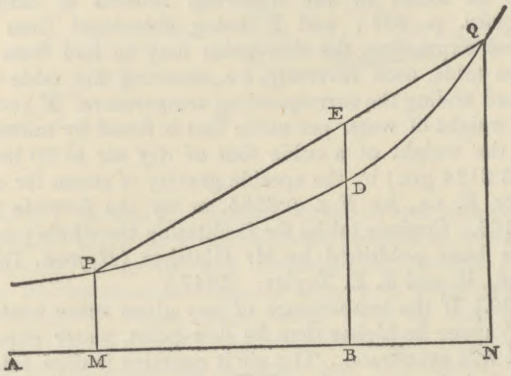

Fig. 4.

(93.) *Radiation Fogs and River Mists.*—When the air in contact with a radiating surface has been reduced in temperature to the dew-point, and has discharged its superfluous moisture in dew or frost, it remains saturated, and at the same time colder than that above it. If the ground be quite level, and the air quite calm, however, little or no mixture will take place, the upper air remaining uppermost, in the absence of any reason for its descent, or for the rise of that beneath. But if the ground slope ever so little towards a valley or hollow basin, the cold air will run downwards, and mixing with the air below, if sufficiently near to saturation, will depress the mean temperature of the mixture below its resultant dew-point, and produce fog. If the low ground be occupied by water or marsh, as the air reposing on it is sure to be saturated, copious precipitation will necessarily result. If dry, the mist produced will be less copious, and *may* not even take place at all. In the Weald of Kent, a district abounding in grassy slopes and winding and branching valleys, in the calm clear nights which are there so frequent, beautiful instances of radiation-fog are of perpetual occurrence. Immediately after sunset, in clear weather, dew commences—streams of cold air set downwards, following the lines of watershed (very sensible as descending currents), their course being marked with mist, thin and filmy at first, but acquiring density in its downward progress, and by degrees filling the valleys with fog, which, in the morning before sunrise, presents exactly the aspect of a winding lake or river of water, whose surface, perfectly even and horizontal, runs a sharply defined level line round every promontory and into every retreating nook. Descending into such a lake, under a full moon, a few yards below its upper surface, *a lunar rainbow is frequently seen* in the mist. We on one occasion resorted to a particular spot, well situated for the purpose, to look for one, and were not disappointed. (Here then, at least, the argument of Kratzenstein for vesicles is inapplicable; and we cannot forbear adding that by far the finest lunar rainbow we have ever been fortunate enough to witness (Nov. 12, 1848) was formed in a dense fog, *evidently close at hand*, and when not a drop of actual rain was falling. On this occasion the exterior or secondary bow was seen.)

(94.) It is a matter of ordinary remark, that the spring frosts are severer in hollows and low grounds than on slopes and heights. This is an obvious consequence of what has been said. The cold air flows downwards, and collects in the hollows, being replaced on the heights by the air of a higher stratum, unchilled by radiation.

(95.) A radiation-fog once formed tends to its own increase, by radiating off heat from its own particles, water in the liquid state being a good radiant of caloric.

(96.) When the warm current in the open ocean encounters a shoal, the lower water (of inferior temperature) is thrown up to the surface. The surface-water, therefore, on the shoal is colder than that of the surrounding ocean, and their atmospheres (saturated at the respective temperatures) mingling, produce those fogs which are observed to be prevalent in such localities. The fogs of Newfoundland are a remarkable instance in point. Fogs, too, are produced in the neighbourhood of floating icebergs, on a similar principle. The Arve, in its descent from Chamouni, occasionally presents the appearance of a river of warm water throwing up steam (though, in fact, many degrees colder than the air), from the mixture of the cold air above it with the saturated warmer air of the valley through which it flows (*Obs.* Aug. 1821).

(97.) *Barometric fogs.*—The temperature of a mass of air may be lowered beneath the dew-point, independent of radiation, contact of a cold body, or mixture with colder air, by the simple effect of its own expansion. This may take place in two ways, viz., 1st, By a rapid and considerable relief of barometric pressure from above; or, 2dly, By its own ascent into a higher region of the atmosphere. The first case takes place when the trough of an atmospheric wave (see art. 75) passes rapidly over the place of observation. The fog so produced comes on for the most part suddenly, and without any obvious cause. It is not rolled in from a distance by the wind, nor does a moderate wind dissipate it. It is not confined to the surface of the ground, but extends at once to great altitudes. It does not resolve itself into rain, but disappears, when the atmospheric equilibrium is restored, by the recondensation of the air, and the reappearance of its sensible heat. Such fogs are very common, and are precisely analogous to the cloud produced in the receiver of an air-pump by a rapid partial expansion of the air. They want a name, and that of barometric fogs seems not inappropriate.

(98.) III. *Clouds.*—When a body of vapour is generated from any warm evaporating surface, it ascends by its relative levity, losing sensible heat, as well by its own expansion as by its bodily transfer into and intermixture with colder air. Should the supply of vapour, however, not be very copious, and should it find itself, in its ascent, always in a region hygrometrically dry, it by no means follows that it will reach the point of precipitation; but should the reverse of these conditions obtain, viz., a copious and continued supply from below, and a state of vaporous tension already existing aloft approaching saturation, a portion will be precipitated, in visible cloud, on arriving at a certain level. When this process takes place in a calm state of the air, and the evaporating surface is limited in extent, or irregularly distributed in patches (as over marshy ground, rivers, lakes, &c.), or if any other cause dispose the vapour to rise in columnar bodies of greater or less extent, the summits of these are marked by protuberant masses or piles of cloud, with generally rounded outlines, which appear to repose on flat bases, indicating the "vapour plane," or that level where hygrometric saturation commences. To such clouds, in Howard's *Nomenclature of Clouds*, the name of Cumulus is assigned. They abound in the calm latitudes of the equatorial seas, and form a distinguishing feature in the meteorology of that region.

(99.) That the mere self-expansion of the ascending air is sufficient to cause precipitation of some of its vapour, when abundant, is rendered matter of ocular demonstration in that very striking phenomenon so common at the Cape of Good Hope, where the south or south-easterly wind which sweeps over the Southern Ocean, impinging on the long range of rocks which terminate in the Table Mountain, is thrown up by them (as marked by the direction of the arrows in fig. 5), makes a clear sweep over the flat table-land which forms the summit of that mountain (about 3850 feet high), and thence plunges down with the violence of a cataract, clinging close to the mural precipices that form a kind of background to Cape Town, which it fills with dust and uproar. A perfectly cloudless sky meanwhile prevails over the town, the sea, and the level country, but the mountain is covered with a dense white cloud, reaching to no great height above its summit, and quite level, which, though evidently swept along by the wind, and hurried furiously over the edge of the precipice, dissolves and completely disappears on a definite level, suggesting the idea (whence it derives its name) of a "Table-cloth." Occasionally, when the wind is very violent, a ripple is formed in the aerial current, which, by a sort of rebound in the hollow of the amphitheatre in which Cape Town stands, is again thrown up, just over the edge of the sea, vertically over the Jetty, where we have stood for hours watching a small white patch of cloud in the zenith, a few acres in extent, in violent internal agitation (from the hurricane of wind blowing through it), yet immovable, as if fixed by some spell, the material ever changing, the form and aspect unvarying. The Table-cloth is formed also at the commencement of a "north-wester," but its fringes then descend on the opposite side of the mountain, which is no less precipitous. Fig. 1, Pl. XIX., is a careful representation of such an exhibition of it on May 20, 1835.

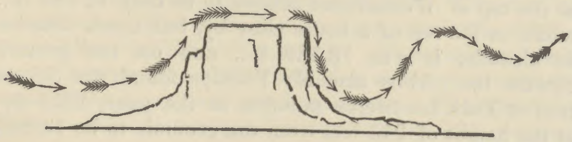

Fig. 5.

(100.) *Nomenclature of Clouds.*—The forms and aspect of clouds are very indicative of the circumstances under which they are in the act of forming or dissipating. Howard (*Askesian Lectures*, 1802) has endeavoured to embody their chief characters in a determinate nomenclature, which has been generally adopted. He divides clouds into three primary modifications: Cumulus, Stratus, and Cirrus, with intermediate forms graduating into one another under the names Cumulo-stratus, Cirro-stratus, Cirro-cumulus, and, lastly, a composite form, resulting from a blending or confusion of the others, under the name Cirro-cumulo-stratus or Nimbus.

(101.) *Cumulus* has been already described. Mr Howard defines it as *sursum crescens*, increasing upward from a horizontal base. This is in conformity with its origin. When sharply terminated by rounded spherical forms, which under sunshine appear as snow-heaps, the form clearly indicates the act of self-dissipation in invisible vapour into the upper relatively dry air.

(102.) *Stratus* consists of horizontal sheets. Its situation is low in the atmosphere, and may be considered as intermediate between cloud and fog, being chiefly formed at night, and under the influence of radiation either from the surface of a ground fog (as already described), or from impurities floating in the air itself. The latter is remarkably the case in great cities in which coal is chiefly consumed as fuel, and gives rise to those dense, yellow, suffocating fogs which infest London in the winter months. A very peculiar phenomenon exhibited by the London atmosphere has been described to us by the Astronomer-Royal, and appears to be referable to the same cause. In calm evenings after sunset, as seen from the Royal Observatory on Greenwich Hill, the vast irregular mass of smoke hovering over London appears to subside. Its heaped and turbulent outline becomes flat, and sinks rapidly into a low level cloud-bank, with a very definite outline, and fair sky above. It would seem that each particle of soot, acting as an insulated radiant, collects dew on itself, and sinks down rapidly as a heavy body. Stratus is also sometimes formed very suddenly on a higher level, when in a clear, calm night the general temperature of the air sinks by radiation, or by diminution of atmospheric pressure, till at some definite altitude above the surface the dew-point is attained. Thus, on the night of April 19, 1827, the sky, up to 16h. 16m. Sid. T, being perfectly cloudless, and not a breath of wind stirring, stratus at a high level commenced in the eastern horizon, and in eight minutes had extended to the western, obscuring the whole sky, the calm remaining unbroken. In this case the velocity of propagation of the edge of the cloud from east to west (or following the sun) could not have been less than 300 miles per hour (*Mem. Ast. Soc.* iii. 51.)

(103.) *Cirrus* consists of fibrous, wispy, or feathery clouds occupying the highest region of the atmosphere. The name of mares' tails, by which cirri are commonly known, describes their aspect well. Of all forms of cloud these present the greatest variety. Their filamentous structure clearly indicates them as either in the act of originating from the union of aerial currents running parallel to each other, or as the residues of dissolving cloud drawn out into fibres by wind. Mr Howard is disposed to assign to them an electric origin, or at least to attribute their fibrous appearance to electricity, but in this view we cannot coincide. From the great elevation of cirrus it is more than probable that its particles are frozen, and of course crystalline, and that to this constitution it is owing that halos, coronæ, and other optical appearances referable to reflexions and refractions in ice crystals, appear almost invariably in this cloud and in its derivative forms, especially the cirrocumulus. It is said to be often a precursor of windy weather.

(104.) The *Cirro-cumulus*, most characteristically known as a " mackarel sky," consists often of small roundish masses disposed with more or less regularity and connection. They usually float at great elevations, and often appear as a loftier stratum through the intervals of lower clouds, contrasting strongly by their slow (and sometimes contrary) movement, with the scud and drift of the inferior masses. They are frequent in summer, and attendant on dry and warm weather.

(105.) *Cirro-stratus* " appears to result from the subsidence of the fibres of *cirrus* to a horizontal position, at the same time approaching laterally. The form and relative position when seen in the distance frequently give the idea of shoals of fish." It often precedes wind and rain, and often forms the ground on which halos and parhelia are projected.

(106.) *Cumulo-stratus* would seem to be the modification of *cumulus*, when the columns of rising vapour which go to form it arrive in an upper atmosphere not sufficiently dry to round off its summits by rapid evaporation, allowing them to spread horizontally and form flat-topped, mushroom-shaped masses, the upper parts of which are often curled by the wind of an upper current into cirrous wisps, or cleanly cut off by a horizontal plane, forming an " anvil-shaped cloud" with a lateral projection, generally considered as a precursor of wind below. Its tendency is to spread, overcast the sky, and settle down into the *Nimbus*, and finally to fall in rain. When two strata of clouds on different levels tend to unite, it is evident that the intermediate region must be nearly or quite in a state of hygrometric saturation. The cloud then forms confusedly and in irregular masses through the whole region, and finally resolves itself into heavy rain.

(107.) When cloud is present, the sun's rays are of course prevented from reaching the earth directly, and their heat is diffused through the general atmosphere—thus softening and mitigating their ardour. When the sun shines on a cloud, which absorbs its heat, the cloud itself is necessarily partially evaporated, and the vapour by its levity tends to produce an upward current, and thus to counteract the effect of gravity on the globules of which it consists. A globule of water 1-4600ths in. in diameter, in air of five-sixths of the density on the surface, or at the height of about 5000 feet, would have its gravity counteracted by resistance, with a velocity of descent of one foot per second (supposing no friction and no drag); and even if the terminal velocity were reduced to half that quantity by these causes, would still require some such upward action to enable it to maintain its level—a circumstance which sufficiently accounts for the lower level generally observed of cloud during the night. It is more than probable, however, that, when not actually raining, a cloud is always in process of generation from below, and dissolution from above, and that the moment this process ceases, rain, in the form of " mizzle," commences. In a word, a cloud in general would seem to be merely the visible form of an aerial space in which certain processes are at the moment in equilibrio, and all the particles in a state of upward movement.

(108.) IV. *Rain.* In whatever part of a cloud the original ascensional movement of the vapour ceases, the elementary globules of which it consists being abandoned to the action of gravity begin to fall. By the theory of the resistance of fluids, the velocity of descent in air of a given density is as the square root of the diameter of the globule. The larger globules, therefore, fall fastest, and if (as must happen) they overtake the slower ones, they incorporate, and the diameter being thereby increased, the descent grows more rapid, and the encounters more frequent, till at length the globule emerges from the lower surface of the cloud, at the " vapour plane," as a drop of rain; the size of the drops depending on the thickness of the cloud stratum, and its density. Rain indeed has been observed to fall (at least apparently) from a cloudless sky, but the occurrence is one of extreme rarity, and it seems hardly possible to be certain that it has not been brought by wind at a high level from very great distances. A very minute rain from a clear sky is known in France by the name of *serein*, and seems to be not uncommon.

(109.) The quantity of rain which falls on any given place may be measured by the very simple contrivance called a " rain-guage," which is an open vessel of a definite aperture (suppose a square foot), and of a funnel shape below, to conduct the rain fallen into a graduated vessel where it can be measured to a nicety, a very minute superficial depth of rain being thus read off on a magnified scale, even though hardly more than enough to wet the surface. It is usually recorded in inches of actual depth, and the wetness of a year or of a season is expressed by the number of inches and parts to which the earth's surface would be covered, if it could neither run off, sink into the soil, or evaporate. Some very extraordinary and unexpected facts respecting the fall of rain have been disclosed by the use of this instrument, which would appear to indicate that its formation is by no means limited to the region of visible cloud. At one and the same place a series of rain-guages, placed at different elevations above the soil, indicate very different quantities of rain, the amount being *greater* at the *lower* level. Thus Dr Heberden found in twelve months, from July 7, 1766, to July 7, 1767, the amount of rain at the top of Westminster Abbey to be only 12·099 in., while on the top of a house close by, but much inferior in altitude, it was 18.139 in., and on the ground 22·608 in. Thus also Mr Phillips found the fall of rain at York for twelve months, in the years 1833-34, at the height of 213 feet from the ground, to be 14·963 in.; at 44 feet, 19·852 in.; and on the ground, 25·706 in. Again, at the Observatory of Paris the ratio of the rain collected during the nine years (1818-1826) on the terrace of the Observatory, and 3 metres from the ground (or 27 metres = $88\frac{1}{2}$ feet lower in level) was that of 1 : 1·116, the difference being much less proportionally than in England, where the ratio from Mr Phillips's observations is that of 1 : 1·719 at 213 feet, and 1 : 1·296 at 44 feet. The usual account given of this phenomenon (Kämtz, i. 419) is that rain falling from a high level, and therefore colder than the temperature of the air at the surface of the ground, arriving in an atmosphere nearly or quite saturated with moisture, condenses on itself, or causes the condensation, in the chilled air, of an additional quantity of vapour. But it is evident that this cause, though not uninfluential, is totally inadequate to account for so great a difference. Admitting a given weight of rain to arrive at 213 feet from the ground, with the temperature of the region at which it was formed unaltered, and supposing it to acquire in the remaining 213 feet the full temperature of the air (both of them extreme and indeed extravagant suppositions), admitting too (though hardly less extravagant) the mean height of formation of the rain to be 12000 feet, it would bring down with it a cold of 40° Fahr., which would condense (whether on the drops or in saturated air if diffused through it) only 40-960ths, or 1-24th = 0·042 of its weight, = one-seventeenth of the quantity to be accounted for. Still less can the effect be due to a greater *obliquity* of fall at a higher than at a lower level, since the same quantity of rain must fall on the same horizontal surface after changing its obliquity as before. Dr Heberden, in the spirit of that meteorology which refers everything not clearly understood to electricity, ascribes an electrical origin to the phenomenon. The real cause is yet to seek, and there is no more interesting problem which can fix the attention of the meteorologist. Visible cloud rests on the soil at low altitudes above the sea-level but rarely: and from such cloud only, would it seem possible that so large an accession of rain could arise.

(110.) The amount of rain which falls habitually per annum in any locality depends on a great variety of circumstances, the most influential being its proximity to large bodies of heated water, such a prevalent direction of wind as shall not drift the vapour away from it, and the absence of any lofty mountains in the direction of the moist wind, to act as a barrier by causing its depositions on them. As we recede from the sea into the interior of great continents rain becomes rare, especially if the soil be sandy. Thus in the Great Sahara of Africa rain is unknown, as also in Arabia and part of Persia, in the great desert of Gobi, in the table-land of Thibet, &c. The greater part of the enormous evaporation of the equatorial seas is at once condensed and discharged again in rain from the cumuli which mark its up-rush into the higher and colder regions of the air, the rain being most continuous in those latitudes between the tropics, over which for the time the sun is vertical, or in the region of the calms. In this zone the nights are for the most part clear, but as the day advances the clouds thicken and pour down torrents of rain, clearing again at sunset.

(111.) Rain is of unfrequent occurrence, however, in the zones on either side of the calms, where the trade-winds blow steadily and regularly. These winds themselves, coming from higher latitudes, are *acquiring temperature and taking up moisture* from the sea. The returning counter-currents having discharged their first overload of moisture, pursue their course aloft, free from cloud and relatively dry; and in the neutral interval between them and the opposite lower current, cloud is not generated, or rain produced, by the intermixture of the two—the upper portions of the trades not being saturated, for the reason just adduced. The clouds which do occur in these winds belong not to their higher strata but to a much inferior level, not exceeding five or six thousand feet in altitude, while the medial line between the winds has nearly double that elevation. Such at least are the phenomena on Teneriffe, as exhibited during the late residence of Mr C. P. Smyth on the summit of that mountain for a fortnight in the month of August, during the whole of which time the sea horizon was never once visible, a stratum of these low clouds lying uninterrupted in every direction, the *upper half* of the peak being free from cloud, and *its summit*, at 12500 feet, just surpassing the medial line, and coming within the upper or SW. current.

(112.) Between the tropics there is, properly speaking, no winter or summer. The year is divided into a dry and wet season—the dry, when the sun is in the opposite hemisphere, and the trade wind blows strong; the wet, when in the same, and approaching the zenith. In the neighbourhood of the equator, where the sun passes the zenith twice at several months' interval, there are two dry and two wet seasons, or rather two unequal maxima and minima of rain. Where monsoons prevail, however, the law of rain is different. Thus, on the eastern coast of the peninsula of India, the rains occur during the north-east monsoon, and on the western during the south-east or trade.

(113.) Beyond the tropics, where the *anti-trade* or returning current descends to the level of the earth's surface, and by degrees takes up the temperature of our milder latitudes, its vapour, held so far in abeyance, becomes available for the production of rain, unless intercepted, as above indicated, by some lofty mountain barrier tossing up the stream and prematurely precipitating its vapour. Where this obstacle does not exist, however, the rains are distributed in the extra-tropical regions with considerable indifference as to season; in some, indeed, a certain approach to a wet and dry division of the year prevails, as, for instance, along the coast of Portugal, as well as in Italy and the south of France, where scarcely any rain falls in summer, while at Pekin the contrary rule prevails. Since, however, the deposit of water from the air, as it travels, must of necessity bear some rude proportion to the actual quantity *in transitu*, the amount of rain or snow which falls on any country must, on a general average, diminish as the latitude increases, a conclusion confirmed by observation.

(114.) The west coasts of England and Ireland form a rather remarkable exception to this law. They receive with the west and south-west winds which generally prevail, the vapour of the Gulf Stream. In consequence the annual fall of rain is not only much greater than on the eastern and southern coasts, but in one district, that of the Lakes of Cumberland, is quite enormous. The annual fall at Seathwaite, in Borrowdale (Lake district) amounted, according to the careful observations of Mr Miller, to no less than 141·54 inches on an average of three years; while that in London is only $23\frac{1}{2}$. To bring this result into comparison with what obtains elsewhere, we subjoin a table (see next page) of the mean annual amount of rain in some of the more remarkable localities.

(115.) Rain, except in the tropical regions, is perhaps the most irregular of all meteorological phenomena, both in respect of the frequency of its occurrence and in the quantity which falls in a given time. The quantities recorded are, in some instances, truly astonishing. It is considered, in the greater part of England, a heavy rain if an inch fall in the course of twenty-four hours; yet at Seathwaite, above mentioned, 6·62 inches are recorded by Mr Miller to have fallen on November 27, 1845, in that time. At Joyeuse (Ardeche), in France, 31·173 inches fell in twenty-two hours; at Genoa, 30 inches in twenty-four hours; at Gibraltar, 33 inches in twenty-six hours. "On the mountain tops overhanging Bombay, 24 inches of rain have been recorded in a single night."—(*Perry, Bird's Eye View of India*, p. 17). These are, however, only sudden, unsustained falls. But in tropical regions we have instances of what may almost be called deluges. Humboldt collected, at Rio Negro, in the rainy season in May, *as an ordinary rain*, $1\frac{3}{4}$ inch in five hours. Admiral Roussin found, for the amount of rain at Cayenne, between the 1st and 24th February 1820, no less than 12 feet 6·96 inches, and on one night, between 8 P.M. and 9 A.M., he collected $10\frac{1}{4}$ inches. At Cherra Ponjee, in the Khasyah mountains, east of Calcutta, nearly 600 inches per annum are stated to have fallen.

PLACE.	LATITUDE.	RAIN per Ann.
		Inches.
Singapore	+ 1° 16′	97.0
Kandy	+ 7 20	52.1
Trevandrum	+ 8 28	64.5
Sierra Leone	+ 8 29	86.2
Uttray Mullay	+ 8 39	267.2
Cape Comorin	+ 8 59	28.4
Allepy	+ 9 27	113.3
Cochin	+ 9 58	106.1
Dodabetta	+11 23	101.3
Grenada	+12 7	112.0
Seringapatam	+12 26	23.7
Madras	+13 4	44.6
St. Helena (Very irregular)	−15 57	45.2
Rangoon	+16 47	84.0
Mahabalishwar	+18 ...	254.1
St. Domingo	+18 29	107.6
Poonah	+18 30	25.4
Bombay	+18 53	75.2
Calcutta	+22 35	76.4
Cherra Ponjee	... ...	592.0
Rio Janeiro	−22 54	59.2
Havannah	+23 9	91.2
Charleston	+32 46	54.0
Madcira	+33 30	27.7
Cape of Good Hope	−33 56	...
Williamsburg	+37 13	47.0
Palermo	+38 8	22.3
Lisbon	+38 42	27.1
Washington, U. S.	+38 54	41.2
Mafra	+38 55	44.0
Pekin	+39 54	26.8
Philadelphia (Gir. C.)	+39 56	37.2
Cambridge, U.S.	+40 5	38.9
Coimbra	+40 12	118.8
Bacou	+40 22	15.2
Tiflis	+41 40	19.9
Rome	+41 54	31.0
Odd years obs^{d}.		13.42
Hobart Town	−42° 52′	18.4
Even years obs^{d}.		23.34
Toulon	+43 9	18.2
Marseilles	+43 17	23.4
Siena	+43 22	34.2
Toulouse	+43 36	25.2
Toronto	+43 40	39.7
Arles	+43 42	23.8
Florence	+43 46	41.3
Orange	+44 7	30.3
Genoa	+44 24	47.3
Bologna	+44 29	31.0
Bordeaux	+44 50	25.8
Rovigo	+45 4	32.9
Turin	+45 5	26.6
Padua	+45 25	36.9
Verona	+45 27	36.9
Vicenza	+45 32	43.8
St. Bernard	+45 50	58.5
La Rochelle	+46 9	24.5
Geneva	+46 13	31.7
Milan	+46 28	37.8
Lausanne	+46 30	40.2
Poictiers	+46 35	23.6
Montpellier	+46 36	32.4
Berne	+46 55	46.1
Zurich	+47 21	34.3
Troyes	+48 18	23.9
Augsburg	+48 21	39.1
Ulm	+48 25	26.8
Tubingen	+48 31	25.5
Lougan	+48 35	13.6
Stuttgard	+48 36	25.3
Paris	+48 50	22.2
Carlsruhe	+49 0	26.4
Metz	+49 5	29.0
Manheim	+49 30	22.4
Nismes	+50 3	25.3
Prague	+50 5	14.1
Cracow	+50° 6′	13.3
Penzance	+50 8	37.2
Gosport	+50 48	29.7
Brussels	+50 17	28.6
Nertschinsk	+51 18	16.0
Coblentz	+51 22	22.2
Bristol	+51 27	23.3
Gottingen	+51 30	26.6
Middleburg	+51 30	27.1
London (Greenwich)	+51 31	24.4
Breda	+51 32	26.3
Rotterdam	+51 55	22.7
Oxford	+51 55	26.5
Strasburg	+52 10	27.3
Lyndon	+52 42	18.3
Nottingham	+53 10	26.4
Franeker	+53 11	30.5
Barnaoul	+53 20	10.5
Dublin	+53 23	29.1
Liverpool	+53 24	34.5
Manchester	+23 29	36.2
Lancaster	+54 3	39.7
Isle of Man	+54 15	37.1
Kendal	+54 19	53.7
Seathwaite	+54 ...	141.5
Gorki	+54 45	18.2
Dumfries	+55 4	36.9
Catherineburg	+55 11	15.6
Zlatoouste	+55 11	17.7
Copenhagen	+55 40	18.5
Glasgow	+55 52	21.3
Edinburgh	+55 57	24.9
Kinfauns	+56 20	24.7
Sitka	+57 34	87.9
Stockholm	+59 20	20.4
Bogoslovsk	+59 45	17.2
Upsala	+59 48	17.8
Petersburg	+59 56	17.3
Bergen	+60 24	88.6

(116.) V. *Hail.*—In a balloon ascent performed by Messrs Green, Rush, and Spencer, on September 4, 1838, after mounting to an altitude of 19185 feet, during which ascent the thermometer, at 12000 feet, marked 46° Fahrenheit, they found, on descending again to the last mentioned level, a temperature of 22° Fahrenheit only, or 24° colder than in their ascent. At the same time, they found there a heavy fall of *snow* in progress. It is evident that this arose from the condensation of vapour *at* that level, and that, from the intrusion of some current, a mass of intensely cold air had been introduced, which, finding vapour near saturation, converted it into snow. It is equally evident that, had the latter condition prevailed not at the level in question, but at a somewhat higher, where the condensation might have been into *rain* very near the freezing point, the drops, in descending, would have been frozen solid and fallen as *hail.* It might have been so equally, had the precipitation been so copious as to allow the coalescence of a great number of minute particles in a nascent state into drops frozen together instanter, since there is good reason to believe that the solid form is never assumed without transition through the liquid, however momentary.

(117.) The generation of hail seems always to depend on some such very sudden introduction of an extremely cold current of air into the bosom of a quiescent, nearly saturated mass. Hailstorms are always purely local phenomena, and never last long. They often mark their course by linear tracks of devastation, of great length and very small breadth. In the hailstorm of July 13, 1788, which passed across France from south to north, two such tracks were marked, of 175 and 200 leagues in length respectively, parallel to each other, the one four leagues broad, the other two, and separated by a tract five leagues in breadth, in which only rain fell. A similar character is very common, though not to such an extent. Such linear hailstorms are always attended with violent wind, sudden depression of the barometer, indicating a great commotion in the air, and probable mingling of saturated masses of very different temperature. To attribute to hail, as is often done, an electrical origin, because hail is often accompanied with thunder and lightning ("hailstones and coals of fire"), seems to us to be putting the effect for the cause.

(118.) Hail may be very properly distinguished into single hailstones and aggregated masses. Single stones have generally a crystalline structure, radiating from a centre if large, forming spherical, oval, or rounded masses, often marked out (on making a section) into concentric layers, like the rings in the section of a branch. They fall from the size of small peas to that of an egg, an orange, or a man's head, and weighing from a few grains up to fourteen pounds and upwards. Dr Thomson, in his *Introduction to Meteorology*, a work in which the reader will find assembled a most extraordinary collection of the recorded marvels of meteorology, gives many instances of the fall of large hail-stones. One, described by Captain Delerosse, as having fallen at

Baconniere, July 4, 1819, fifteen inches in circumference, had a beautiful radiated structure (fig. 6), marking it as a single stone, formed in passing through two distinct regions of condensation. Dr Buist stated to the Bombay Geographical Society, that in India the hail-stones are from five to twenty times larger than those in England, often weighing from six ounces to a pound, seldom less than walnuts, often that of oranges and pumpkins! These storms are almost always accompanied by violent wind and rain, thunder and lightning, and are frequent in the delta of the Ganges, especially in the low country within fifty miles of the Bay of Bengal.

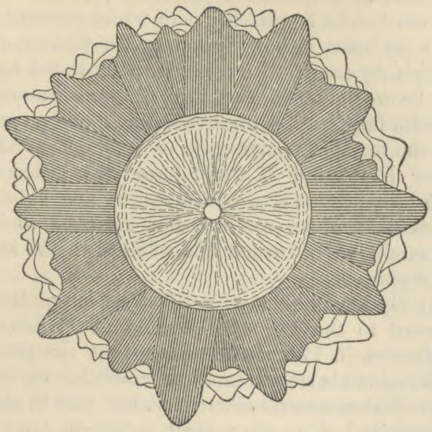
Fig. 6.

(119.) Great hail-storms are often preceded by a loud clattering and clashing sound, indicating the hurtling together of masses of ice in the air. The recent experiments of Professor Tyndall on the reuniting of broken ice by "regelation," or a sort of welding, fully explains the formation, under such circumstances, of large masses of ice of irregular forms in this aerial conflict. Such are recorded to have fallen of almost fabulous magnitude. In Candeish, in 1826, in a hail-storm which perforated the roofs of houses like small cannon shot, a mass fell which took some days to melt, and must have weighed more than a hundred-weight.—(*Malet.*) On May 8, 1832, a mass fell in Hungary a yard in length and nearly two feet in thickness.—(*Thomson.*) And if it be true, as stated in the *Ross-shire Advertiser* in 1849, that a block "of irregular shape, nearly twenty feet in circumference," fell in August of that year on the estate of Mr. Moffat of Ord, immediately after an extraordinarily loud peal of thunder, Heyne's relation of a hail-stone as large as an elephant, at Seringapatam, in the reign of Tippoo Sultan, may perhaps find believers. The Ross-shire mass is stated to have been composed of lozenge-shaped pieces, one to three inches in size, firmly congealed together.

(120.) VI. *Snow.*—When time is allowed, and the process of precipitation and congelation takes place in a less tumultuous manner, so as to allow the deposited particles to accrete according to regular arrangements, small spiculæ form, crossing one another at angles of 60°, the primitive crystal of ice being a rhomboid of 60° and 120°, producing as one of its secondary forms the regular hexagonal prism, having (as all such crystals) one axis of double refraction parallel to the axis, as is easily seen in a sheet of ice formed in still water on exposure to polarized light. When deposited as hoar-frost in the condensation of dew, the crystallization is confused by contact with and adhesion to the radiant body, but when supported only by air and receiving accretion on all sides, a high degree of regularity is attained, and the most perfect and symmetrical six-rayed star-like forms arise, of which (drawn from actual observation of the falling spangles, in very cold weather) Dr Scoresby has given several figures, and Mr Lowe and Mr Glaisher have more recently published series of engravings. The variety of forms affected by these delicate mechanisms is infinite; the beauty of their patterns incomparable. By Mr Glaisher's permission we have transferred a few of his figures to our pages (Pl. XIX., figs. 2-15). Mr Lowe has been fortunate enough to observe them in the act of forming, and to witness the whole process of construction of some of their most elegant and complex varieties.

(121.) It can hardly be doubted that clouds at great elevations consist of frozen particles. The phenomena of parhelia and some species of halos are explicable only by the refraction and reflexion of light in prisms, with angles of 120° and 60°, as M. Bravais has shown (following up the theoretical views of Mariotte and Young) by a neat and elegant mechanism. Now these are the angles of the primitive rhomboid actually measured by Dr Clark. In *such* clouds, at all events, vesicles cannot exist, and in the gradual melting of the snow spangles, the laws of capillary attraction, by filling up all re-entering corners, would effectually preclude the inclusion of the smallest air-bubble, though a compound snow-flake hurriedly melted might now and then entangle one.

(122.) Fallen snow of even a very moderate depth, is a powerful agent in mitigating the extreme effects of frost on the soil. Owing to its loose texture and its inclusion of eight or ten times its bulk of air, it is a very bad conductor; and although its upper surface may be cooled by radiation or otherwise to a very low point, its interposition cuts off the communication between the chilled surface and the soil beneath it. The farmer looks to a fall of snow as his best security for the preservation of his autumn-sown and sprouting crops through the winter.

(123.) *Level of Perpetual Snow.*—Since by ascending into the atmosphere a temperature inferior to congelation is everywhere met with, it is evident that a mountain of some certain elevation will have the mean temperature of its summit at or below the freezing point; and although it does not follow that where the mean temperature is precisely 32°, snow will necessarily be found all the year round (since this will depend on the greater or less accumulation of it in the cold seasons, and on the greater or less evaporation in the warmer ones), yet, somewhere about this limit, and at all events at no great elevation above it, we must expect to encounter the phenomenon of perpetual snow. If we take 1° Fahr. for the average depression of the thermometer for 100 yards of increased altitude in mountain ascents, as a rough approximation, and assume 84° for the mean equatorial temperature, this would give $(84-32) \times 300$ ft. $=15600$ ft. for the height above the sea level, at which, under favourable circumstances, the perpetual snow line may occur under the equator; we say under favourable circumstances, for it is evident that if the mean temperature of the year be ever so little above the freezing point, we cannot expect snow to lie all the year round, especially on the summit of a mountain where all the water produced by melting immediately runs off, and therefore ceases from that moment to act as a reservoir of cold. Now the mean of Humboldt's determinations of this element for the mountains of equatorial America from 4°.46 N. lat. to 1°.30 S. (*Asie Centrale*, p. 461, tab.) gives 4774 metres $=15670$ feet.

(124.) This, however, must be considered as a *minimum* reckoning. In the celebrated work just cited, Baron Humboldt has given a table of the most authentic determinations of the snow-level for 34 mountains *trigonometrically* measured from 71° N. lat. to 54 S. Of these the mean annual temperatures *at the sea-level* are correspondingly stated for 18 stations — calculating on which it would appear that about 2100 feet on an average ought to be added to the height calculated on the decrement of temperature assumed in the last article, to give that of the snow line.

(125.) In fact, however, no general rule or principle of calculation can be laid down, and though attempts are not wanting to construct formulæ which shall afford a close approximation to the height in any geographical position, it is impossible to place any reliance on them. This will be the more evident when we come to consider the causes which must of necessity influence the result. Of these the principal are—1st, The situation of the slope on which the snow lies on the mountain chain, with respect to the incidence of the sun's rays. Thus, on the southern declivity of the Maladetta in the Pyrenees, the level in question is nearly 1200 feet higher than on the northern; 2d, and more especially its situation with respect to the direction of the wind, which brings the chief supply of moisture to be deposited in snow, and which will naturally be heaped on that side of the mountain which acts as an obstacle to its progress. To these causes must be added, 3dly, the greater or less steepness of the slope; and above all, 4thly, the greater or less degree of habitual *dryness* of the region in which the mountain is situated, by which the snow itself is evaporated and carried off. So great is the influence of these causes, that in the Himalayas, where some of the mountain peaks attain the enormous altitude of 28000 feet, the snow line on the southern side of the great chain occurs at 13000 feet, and on the northern at 16600, or even (according to Mr Lond) 18300, the moist winds of the SW. monsoon depositing their snow almost wholly on the southern side, while the northern is exposed to the evaporation of one of the driest regions of the globe. On the other hand, on the eastern slope of the Cordillera, in Chili, the snow-level occurs at 15900, while on the western it rises to 18500 (Humboldt's *Asie Centrale*, iii. 360), the difference again being attributable to the direction of the wind (the SE. trade), to which the chain of the Andes forms a barrier, and of which, to a certain extent, it diverts the course, and the excessive aridity of the region between the chain and the Pacific, in which rain is a thing almost unknown. Apart from the illustration it affords of the distribution of temperature in different strata of the atmosphere, the subjects of the level of perpetual snow, the inferior prolongation into glaciers, and the occasional instances where ice occurs in caves far below the snow-line, preserved throughout the summer (or even in open pits, as in the quarries of the Niedermennig on the Rhine), belong rather to physical geography than to meteorology proper.

(126.) VII. *Atmospheric Electricity, Lightning, Thunder, &c.*—The community of nature between lightning and electricity was suspected from the very earliest discovery of the electric spark, by Wall, in 1708, but it was not till 1752 that Franklin suggested the idea of obtaining evidences of their identity by erecting pointed metallic conductors properly insulated. The experiment was tried in France with success, but Franklin, tired of waiting for the erection of a pointed rod on a spire in Philadelphia, had the happy idea of flying a kite and exploring the string for electricity. The experiment succeeded, meriting by its success that sublime image which forms the inscription on one of his medals,

> "Eripuit fulmen cœlo, sceptrumque tyrannis."

Franklin's kite was flown with ordinary pack-thread, held by a few feet of silk line, and the electric effects obtained by him were feeble, though sparks were produced. But Romas, using in place of a string, a fine wire, obtained, during a thunder-storm (1757), flashes of fire nine or ten feet in length, thirty of which succeeded each other in an hour, besides innumerable flashes of seven feet, which, by means of a conductor, insulated by a glass handle, he was enabled to direct at pleasure—not altogether with impunity, being struck down on one occasion; though the terrible catastrophe of July 26, 1753 (when Professor Riehmann of Petersburg was killed on the spot while explaining to a companion the construction and movements of an electrometer attached to his conductor) might have warned him of the dangers attending such experiments.

(127.) By means of a wire 370 feet long, attached by a silk cord to the top of a steeple at Maintenon, the Abbé Mazeas, in 1753, ascertained that the presence of a thunder-cloud is not an essential condition for the manifestation of atmospheric electricity, but that in clear, dry, and especially hot weather, electric effects are produced at all hours between sunrise and sunset. He even noticed a certain regularity of diurnal increase and decrease. From that time the exploration of atmospheric electricity has formed a part of meteorological enquiry. It is performed by erecting in a clear exposure, at a considerable height, a pole, carrying at the top an insulated and pointed metallic rod, connected with an insulated wire to convey the electricity into a fitting place for examination. There it communicates with an electrometer, a Leyden jar, a condenser, or an apparatus for measuring the length of the spark (if any), by which the kind of electricity (vitreous or resinous) may be tested, and its intensity measured and registered. When violent, a bell is made to ring by the alternate attraction and repulsion of a metal ball, suspended by a silk thread. The best collector of electricity, which is often used when a rod like a fishing rod, with an insulating handle, is thrust out from an upper window, is a bit of amadou, held in a metallic forceps, the smouldering smoke of which being an excellent conductor, as it were searches the air into which it ascends, and conveys its electricity down to the wire attached. A sponge moistened with alcohol, and set on fire, is also an excellent collector.

(128.) Read, to whom we owe a very elaborate series of researches, continued almost hourly, without intermission (except for sleep), for two years (1791-2). Coulomb, Cavallo, Saussure, Schubler, Colladon, and others, have shown that the normal character of aerial electricity is positive or vitreous. Of 987 trials, Read found that 664 gave positive indications; but as his method of observation improved, he found that the ratio of positive cases increased; and moreover, that a great number of the negative were only apparent, arising from induction, the top and bottom of his rod giving contrary indications. Out of 10500 observations made at the Kew Observatory in 1845-47, 10176 showed positive, and only 364 negative electricity—the latter being almost always accompanied with heavy rain.

(129.) Not only is the normal electricity of the atmosphere positive at all seasons, hours of the day, and places, but the intensity of its manifestation is invariably greater the higher in it a conductor is raised. This would appear to be the case even in the very highest regions. Thus in Gay Lussac's ascent, a wire 150 feet long, hung from the car of the balloon, manifested a *negative* state of induced electric tension at its *upper* extremity (where only it could be tested), thus indicating a higher state of positive electricity in the highest strata; or, in other words, the usual condition of electric observation on the ground being reversed, and the state of the *lower* strata being explored by the wire, it was found to be *relatively* negative. Hence it manifestly follows that, relatively to the air, the earth's surface is habitually negative—the positive electricity being repelled inwards, and the negative drawn to the surface. As moisture is withdrawn from the lower strata of the air, by deposition in dew when evaporation ceases; so electricity, when not in the act of being supplied from below (as presently to be shown), is perpetually, though slowly, drawn off by conduction.

(130.) Fog is, for the most part, strongly electric, and invariably positive, even during the deposition of dew. Read found the vapour near the ground, in the act of condensing into dew, always highly electric. The importance of this remark will presently appear.

(131.) From the observations of Saussure, Arago, Schubler, and others, it appears that the electric tension of the atmosphere is subject to a diurnal periodicity with a double maximum and minimum. The maxima occur about 10 A. M. and 10 P. M., and the minima from noon to 4 P. M., according to the season (summer or winter), and a little before sunrise. The nocturnal minimum is much more strongly marked than the diurnal. The electric tension is also stronger in winter than in summer. On the open sea, except during storms, there is but little indication of atmospheric electricity, but the masts and rigging of ships interfere greatly with the requisite arrangements for observing it.

(132.) The origin of aerial electricity has been traced with every appearance of probability to evaporation. Saussure and Beccaria proved by many experiments that the rapid evaporation of water from heated bodies gives rise to a separation of the vitreous and resinous electricities (see ELECTRICITY), the one being carried off by the vapour, the other remaining in the residue or being conducted away by its support, but nothing uniform or consistent either as to the positive or negative character of the electricity thus conveyed into the air, or its amount under given circumstances was obtained, until the subject engaged the attention of M. Pouillet, who, in a remarkable memoir read to the Academy of Sciences in 1825, announced the following results:—1*st*, Simple change of state from the solid or liquid to the vaporous form of any body, is unaccompanied by any electrical excitement. The evaporation of pure water or of any substance not decomposed, or at least partly decomposed in the act, produces none whatever. 2*d*, When evaporation is accompanied with chemical change, electricity is developed. Water evaporated from alkaline solutions carries off resinous and leaves behind vitreous electricity. The reverse happens when it evaporates from an acid, or from neutro-saline solutions, including that of sea salt, or from heated iron which it oxidizes. 3*d*, The processes of vegetation in which water is abundantly separated from the other constituents of plants, and perhaps also their disengagement of oxygen under the influence of light, or carbonic acid under contrary circumstances, are also sources of electricity.

(133.) Thus we are led to look to the immense evaporation both from sea and land, and to the vital processes going on in the latter, as furnishing at least the chief supply of electricity to the air. Volcanic eruptions and conflagrations contribute their quota. Thus in the great eruption of Vesuvius in 1794, described by Sir William Hamilton, the dense cloud of mixed vapour, smoke, and ashes, which overhung the mountain, was overcharged with lightning, which darted around in continual flashes (*ferille*) upon Somma and the slopes of the crater. Wind, too, by its friction, or by that of the dust, &c., which it carries with it, may also contribute somewhat to the general stock.

(134.) In what state free electricity exists in gaseous matter is at present a mystery. The simplest conception we can form, is that of its investing the ultimate molecules of vapour as an electric coating of infinitesimal tension, far too feeble to discharge itself from one to the other, and so to escape by what is called "*conduction through a moist atmosphere.*" If this be granted, we can conceive the co-existence at a distance from each other of masses of air oppositely electrified, and equally capable of giving out a portion of their contents by *contact discharge*, to a rod, wire, flame, &c., and thus explain the collection of electricity by these means from the air, and its diversity of character as to *plus* and *minus*.

(135.) But whatever may be the state of the ultimate molecules of vapour, it seems impossible but that when a great multitude of them lose their vaporous state by cold, and coalesce into a drop or snow-spangle, however minute, that drop will have collected and retained on its surface (according to the laws of electric equilibrium), the whole electricity of its constituent molecules, which will therefore have some finite, though very feeble tension. Now, suppose any number (1000 for instance) of such globules to coalesce, or that by successive deposition one should gradually grow to 1000 times its original *volume*. The diameter will be only 10, and the surface 100 times increased. But the electric contents being the sum of those of the elementary globules, will be increased one thousandfold, and being spread entirely over the surface, will have a tenfold density (*i. e.* tension). This simple view of the subject, put forward in the most distinct form, at the very origin of the discussion of the nature of lighting by Eeles (*Phil. Tr.* 1752, p. 527), needs only to be carried a very little farther than the then state of electric knowledge enabled its author to do, to render a complete explanation of all the ordinary electric phenomena. And, first: the comparatively high electric state of fog (and cloud is nothing else), is an obvious consequence of it. Every minute globule of water, of which fog consists, carries about with it an electric coating, which it is ready to part with by constant discharge to the surface of any conductor, and the denser the fog, and the larger its globules, the greater the amount of electricity given out. Again, the electricity of the superficial air occasioned by the deposition of dew, is in perfect accordance with this view, and is a corollary from the general proposition too obvious to need insisting on. Again, as regards the diurnal fluctuation, when the air is exhausted of its vapour by night deposition in dew, and by upward diffusion without a new supply, the electricity is at its minimum. It increases as new vapour rises under the influence of the ascending sun, decreases again (though not much) as the increasing warmth of the air renders it more capable of holding the still larger amount of vapour uncondensed, and as the vapour itself rises rapidly to form cloud, increases again as night comes on, dew begins to form at sunset, and vapour to settle into globules by atmospheric radiation, and once more decreases as the quantity of these electrified globules diminishes by deposition and diffusion. There is no doubt a certain amount of slow conduction back into the soil, the intimate nature of which it is very difficult to conceive rightly, but of which the phenomena of electricity of weak tension furnish abundant examples by which a considerable portion of the electricity near the surface is returned to the earth, and which is more effective, the more "relatively moist" is the air, and by which the march of the diurnal fluctuation, and its epochs of maxima and minima, are materially influenced.

(136.) When condensation of vapour takes place aloft, as when a cloud is formed, the tension on the surface of its globules may increase by the process explained, till a portion of the electricity is enabled to work its way to the surface of the cloud, regarded as a conductor, though a bad one, by the general law of electric equilibrium, which tends to throw out the fluid to the surface, and universally, no doubt, the exterior of a cloud is in a higher state of tension than the interior, and its under surface, as opposite the earth, than its upper. When the almost infinite dimensions of a cloud, in comparison with one of its constituent globules, is considered, it must be evident that, were the whole electricity of each globule thus at once determined to the surface, a tension so enormous would arise as would discharge the whole in a single flash, at whatever height the cloud might be. But this is assuredly not the case. Probably but a very minute fraction of the interior electricity is at once conveyed to the surface, the further communication being delayed until the exterior tension is relieved, either by slow dissipation or by self-discharge. When this happens, the accumulation commences anew by the same kind of percolation (if we may use the term to express the outward struggle of the electricity of the globules), till another and another discharge at length exhaust the supply.

(137.) It will easily be seen, that when thousands of these electriferous globules again further coalesce into rain drops, a great and sudden increase of tension at their surface must take place. Their electricity, then, is enabled to spring from drop to drop, and rushing in an instant of time from all parts of the cloud to the surface, a flash is produced. Accordingly, in thunder-storms, it is the commonest of all phenomena to find each great flash succeeded by a sudden rush of rain at such an interval of time as may be supposed to have been occupied in its descent. The sudden precipitation of large quantities of rain, and especially of hail, which is formed in a cold region where the insulating power of the air is great, is almost sure to be accompanied with lightning, which the usual perversity of meteorologists, where electricity is in question, long persisted, and even yet persists, with few exceptions, in regarding as the cause, and not the consequence of the precipitation. The theories of the electrical formation of hail which have been advanced, indeed appear to us too absurd to need a moment's consideration. The utmost amount of electrical agency which we can conceive influential in determining precipitation, is the sudden relief of tension on the discharge of a flash, which may permit, and perhaps by the vibration of the air in the thunderclap cause, the coalescence of *globules* into *drops*, which would otherwise have been kept asunder by their mutual repulsion. As a cause of winds, or any atmospheric movements not merely molecular, we attribute to it no importance whatever. As a chemical, and still more as a magnetic agent, however, there is every reason to believe atmospheric electricity to play a very important part in the economy of nature, as we cannot but admit the possibility at least of a connection between the diurnal variations in the electric state of the general atmosphere and the diurnal inequalities of terrestrial magnetism; and the transformation of oxygen into ozone (the most powerful of all known disinfectants) by the electric spark (and therefore on a larger scale by lightning), is not a matter of conjecture but of experiment.

(138.) There is one phenomenon which at first sight seems opposed to the view we have taken of the production of lightning—the negative electricity frequently observed during the descent of rain. But the researches of Faraday (*Phil. Trans.*, 1843) have shown that the friction of water-drops (when pure) against all substances (and therefore probably against air) develops negative electricity most powerfully in the substance rubbed. And the probability is converted into certainty by the fact that the spray of a descending waterfall fills the air around with negative electricity, sensible even at several hundred feet distance. It is probably to this cause that we must attribute the rapid alternations of positive and negative indications in the atmosphere which always attend thunder-storms.

(139.) It is certain that the flashes of lightning are often some miles in length. The prolonged roar, interrupted by explosions, of the thunder, which, excited at the same instant along the whole course of the flash, reaches the ear in succession by the transmission of sound at a uniform rate from every point, sufficiently proves this. Nothing is more common than to see flashes of lightning subtending at the eye an angle of 30°, the nearest point of which, estimated by the commencement of the thunder, cannot be less than two or three miles distant, and which its prolongation proves to be very oblique to the line of sight. We have been assured by a celebrated Abyssinian traveller, that he has seen flashes in that country extending from horizon to horizon, and which he could not estimate as under 50 or 100 miles in length. It is evident, then, that the electricity in lightning does not merely spring across a nonconducting interval to the nearest object (which in most cases would be the earth), but finds a path of ease, and is led on from interval to interval (as its zigzags denote) along a line of least resistance, and is not improbably reinforced in its course by other electricity not of itself intense enough to break the obstacle opposed to its escape.[1] By far the greater number of discharges are made into air or into less electrified cloud, and only a very small percentage into the earth.

(140.) Of those which do so, the destructive effects are well known, and volumes might be filled with instances of their amazing power, and capricious and unaccountable forms of its manifestation (Arago, *Bureau des Long.* 1838.) We shall mention only one or two as specimens. In a storm at Ludgvan, in Cornwall, as related by Borlase, *Phil. Trans.*, 1753, a flash of lightning striking a chimney-stack of hewn stone four feet square, carried it bodily away, and threw it into a pond twenty feet distant. In another, described by Arago, a wall containing twenty-six tons of brick-work was carried *en masse*, retaining its vertical position, nine feet from its place. We have seen a large oak tree, near Alton, Hants, which was rent into ribands, and every limb of which had been struck off as if by an axe, and had fallen around the tree, as by mere privation of support, without lateral projection. In producing these effects, the electricity would seem to act immediately by the expansion of vapour generated by its violent heat. When it strikes into deep sand, it produces those extraordinary hollow tubes *of fused quartz!* known as "fulgurites," of which the British Museum possesses a magnificent specimen, dug out near Dresden by Prof. Fiedler. Other effects of lightning are recorded in the Athenæum, No. MDXXXV., March 28, 1857, too marvellous to be recounted here, but which, should they be verified, would open quite a new field of inquiry in electrical research.

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[1] This is not a mere hypothesis. In an experiment suggested by the author to the late Professor Daniell, and performed as soon as suggested, the striking distance of a voltaic battery was greatly increased by passing a common electric spark from the positive to the negative pole. The vastly increased striking distance of a magneto-electric combination in the neighbourhood of flame, in which its detours may be observed, affords a perfect illustration of the process described in the text.

(141.) Thunder-storms occur with very unequal frequency in different geographical situations. In Jamaica, according to Mr Graham Hutchinson, a thunder-storm bursts over the mountains near Port Royal every day from the beginning of November to the middle of April, at about 1 h. P.M., continuing about an hour and a half. In the neighbourhood of Cape Town, thunder-storms are few and feeble, while on the eastern coast of South Africa they are frequent and violent. The one region is arid, the other well watered.

(142.) The quantity of electricity discharged during some storms must be enormous. In the storm of Aug. 23-4, 1855, the blaze of lightning was almost uninterrupted for many hours, from a series of clouds passing from west to east, in two lines, over the south of England. The commencement of the SW. monsoon in India, in May 1848, was marked by "a thunder-storm extending over 600 miles from N. to S., and measuring 50 miles in breadth." The thunder-storm of September 3, 1841, "visited at the same time London, Paris, Rouen, Magney, Lille, and Evereux."—(*Thomson*). The mere evaporation of water would seem at first sight inadequate for the supply of so vast an expenditure, were it not that we learn from Dr Faraday that the chemical action of a "grain of water on four grains of zinc can evolve a quantity of electricity equal to that of a powerful flash of lightning!"—(*Phil. Trans.*, 1834, p. 117.)

Systematic View of Meteorological Periodicities — General Principles of Climatology.

(143.) The climatology of the globe is the summary of our knowledge of the climates of all the places on its surface, so presented to our minds as to convey the notion of law, and give it an ideal unity. To do this it is necessary to study *seriatim* the elements which enter into our estimate of climate, and follow out the course of the variations of each,—1*st*, independently of the others, and then in connection with them, or, in other words, to determine for each of these elements, 1*st*, its mean or average amount, as measured in its appropriate units; 2*dly*, the extent and laws of its deviations from that amount; and, 3*dly*, their mutual interdependence, or the reaction of each element on the rest. Such features as are not susceptible of definite measurement, as have no appropriate units, or as we have no instruments competent to measure, must of course be excluded. Looked upon in this general point of view, the science in question can hardly be considered as advanced beyond its infancy.

(144.) It is a dynamical law absolutely universal, and one which extends even beyond the domain of mere dynamics, that all periodicity in the action of a cause propagates itself into every, even the remotest, effect of that cause, through whatever chain of intermediate arrangements the action is carried out. When the effect is indirect, and especially when it is the result of one and the same law of periodicity in the same cause operating circuitously through several systems of intermediate connection, the numerical valuation of the effect (which, in the simplest case of direct action, depends on the calculation of an expression of the form $A + B . \sin. (nt + C)$, where A is the mean or average value of the result, B, C constant quantities, and nt an arc proportional to the time directly, and the length of the period inversely) resolves itself into that of a series of similar terms, containing not merely nt, but its multiples $2\,nt$, $3\,nt$, &c., each with its own appropriate constants, and which therefore run through their periods respectively in half, one-third, &c., of the period from which they originate. Thus, if the original period be a diurnal one, and θ be the time converted into arc at 15° per hour, the ultimate expression of the effect will always put on the form

$$E = A + B \sin. (\theta + C) + B' \sin. (2\,\theta + C') + \&c.,$$

in which A is the mean or average value of the effect in question, and B, C, B′, C′, &c. constants determined *a priori*, if such determination be possible; if not, by observation from the comparison of as extensive a series as possible of registered values corresponding to determinate instants of time. The term containing θ, which runs through its period in a day, expresses the leading feature of the effect—that which gives it its character of a *diurnal* fluctuation; the others, which run through theirs respectively in 12h., 8h., 6h., &c., express subordinate fluctuations, more or less materially modifying the law of its increase and diminution, and the epochs of its maximum and minimum, and in certain cases giving rise to double maxima and minima in the twenty-four hours. In meteorology, it has hitherto been seldom found necessary to carry such series out beyond their third terms.

(145.) When the acting cause is subject to two or more distinct periodical fluctuations, these make their appearance in the numerical expression of the effect under the form of periodical combinations, such as may arise from multiplying together terms of a similar form containing nt, and another arc $n't$ similarly derived from the other period. In astronomical researches these are usually resolved into sines and cosines of the sums or differences of nt, $n't$, and of their multiples. But in meteorology this would be inconvenient, and a different mode of regarding such combinations is found preferable for the following reason:—

(146.) The sun's action being the ultimate efficient cause of all meteorological change, every meteorological fluctuation of a regular character will arrange itself, on the principle above laid down, into diurnal and annual periodicities, including under this expression semi-diurnal and semi-annual ones, &c., and such as may result from their superposition (leaving out of question the period of 11·11 years, depending on the constitution of the sun itself, see art. 7). But the year being a very great multiple of the day, we may regard the solar agency as practically invariable during a single day, or such a small number of successive days as may suffice to bring out the full diurnal effect, which comes to the same thing as adopting in general the diurnal form of expression,

$$E = A + B . \sin. (\theta + C) + B' . \sin. (2\,\theta + C') + \&c.$$

for the fluctuating effect, and regarding the co-efficients A, B, C, &c., as constant for any single day, but each subject to an annual periodicity, and as being, each of them, expressible under the same general form, substituting for θ the corresponding annual arc—for which, if we choose, we may use the sun's mean longitude. Thus each of the co-efficients of the diurnal formulæ,

$$A + B . \sin. (\theta + C) + B' . \sin. (2\,\theta + C') + \&c.$$

comes to be regarded as itself a periodical function of the form,

$$a + b . \sin. (\Theta + c) + b' . \sin. (2\,\Theta + c') + \&c.,$$

Θ being the sun's mean longitude.

(147.) Every one of these co-efficients, whether diurnal or annual, generally considered, is dependent on the geographical position of the place of observation; in other words, is a function of the latitude, longitude, and elevation above the sea-level of that place, which, being arbitrary and of unknown form, may be considered as embodying all the local peculiarities of whatever nature; and it is not until all these co-efficients are determined, or at least all which have an appreciable magnitude, for each meteorological element—in temperature, barometric pressure, tension of vapour, rain, &c., wind, and electricity—that the climate of the place can be said to be fully known.

(148.) Any one of these functions, though its analytical form may be quite beyond the reach of our enquiry, yet, by a sufficiently extensive and continuous combination of observation and calculation, carried on upon a system presently to be explained, may become known numerically, and tabulated for every accessible part of the globe; and being so tabulated, the points at which it has equal values may be laid down on a globe or chart, and being connected by a continuous line, and this done for a succession of values, progressing by convenient and regular intervals in its scale of magnitude, from the maximum which it has in any part of the globe down to the minimum which occurs anywhere; a series of level lines, or isometeoric lines (if we may coin a word to convey the general notion) will arise, which will present to the eye the progression and connection of this particular co-efficient over the world. Exactly as if wishing to convey, for instance, an idea of the exterior form of the solid surface of the globe, we should commence by delineating the coast-lines of the continents and islands, which are the level-lines for 0 ft. from the sea-level, and similarly laying down points wherever the height of 100 ft. above, or depth of 100 ft. below, the sea occurred, and connecting them, should get the level lines of + 100 ft. or — 100 ft., *i.e.*, what would be the coast-lines were the sea to rise or sink 100 ft.; and so on, to the tops of the mountains and extreme depths of the ocean.

(149.) This mode of exhibiting to the eye by a picture (a picture which might become a model by executing it in relief) the law of variation of a function known only by observation, over the surface of the globe, or any particular district of it, was first devised by Halley to express the law of the variation of the magnetic compass, but first introduced into meteorology by Humboldt, to exhibit the law of distribution of temperature, by laying down a system of *Isothermic lines*, or those in which the *mean annual temperature* is alike throughout; that is to say, in which the co-efficient, a, in the expression for the mean temperature of the whole year, viz., $a + b \,.\, \sin.\,(\Theta + c) + \&c.$, is constant; and which, therefore, serve to connect in idea, as places having at least one very eminent meteorological feature in common, all those points in the globe which receive (from whatever cause) the same annual total of heat. To these lines we shall recur hereafter. Climatology as a science (or rather as a branch of physical geography, to which, rather than to meteorology, it properly belongs), would be complete, or nearly so, if we possessed a complete atlas of such charts, each containing the isometeoric lines for all the really influential co-efficients, both annual and diurnal (which are not very numerous), exhibiting the mean values of each of the annual co-efficients from the observations of many years, and the mean values and annual maxima and minima of each of the diurnal ones. Hitherto only a few of such lines have been traced, and that imperfectly, viz., the lines suggested by Humboldt, or the *Isothermal*, *Isotheral*, and *Isocheimal* lines, or those in which the *general* mean temperature, the mean *summer* temperature, and the mean *winter* temperature are respectively constant; the *Isogeothermal* lines of Kupffer, in which the *mean temperature of the soil* is constant (and which are not always identical with the Isothermals), the Isobarometric lines of Kämtz, in which the limits of fluctuations of barometric pressure are equal (a series of which it is not easy to see the use), and a few others. We shall now proceed to consider by what means such knowledge can most readily and effectually be attained.

(150.) *Determination of Meteorological Averages and Co-efficients.*—The general form into which, as we have seen, every meteorological *quantitative* expression can be thrown, clearly indicates the system of observation which ought to be followed, so as to lead most directly to a knowledge of their mean values. It is a well-known property of the sine or cosine of an arc, that if the circumference be divided into any number, n, of equal parts, θ, we shall have,

$$\sin.\,(\theta + c) + \sin.\,(2\,\theta + c) + \ldots\ldots \sin.\,(n\,\theta + c) = 0$$

Suppose, then, we would ascertain the diurnal mean, A, of any element, E, supposed to be expressible as in art. 144. Were we sure that E contained only one periodical term, $B \,.\, \sin.\,(\theta + C)$, it would suffice to make a series of observations at intervals of 12 hours, on summing up which, as the + and — values of this term would destroy each other, the sum divided by the number would afford the value of A. If an eight-hourly interval be substituted for a twelve, a like summation will eliminate the terms depending both on θ and $2\,\theta$; if a six-hourly one, those depending on θ, $2\,\theta$, and $3\,\theta$, and so on. So far as meteorological computation has hitherto been carried, this would appear to be in most cases sufficient, the co-efficients of the successive terms diminishing rapidly. From a simple observation *per diem*, no average can be concluded, except it be made at such an hour as experience shows to be that on which the quantity observed has usually its mean value. This differs for each element and for each locality, and is itself a desirable item of meteorological inquiry.

(151.) Annual means may be obtained by summing diurnal ones. If the series be incomplete, two courses may be followed, viz., 1*st*, By subdividing the year into monthly groups, calculating the means for each month from the observations recorded, and taking a mean of the twelve results; or, 2*dly*, By striking out days corresponding to those deficient at 3- or 4- monthly intervals from each.

(152.) The *law of fluctuation* requires us to know the values of the several constants which enter into the periodical terms. To do this effectually from a series of recorded observations, requires the application of the "method of least squares." If the observations be numerous, and made at irregular hours, this is attended with a frightful amount of calculation; but if they form a regular series made at definite hours of the day, and either complete, for many days, or *capable of being completed by the insertion of the deficient observations according to any observed law of progression, or in the absence of such law, by a mean of the adjacent day's observations at homologous hours*, nothing can be simpler or more expeditious than the treatment of such a series by least squares, so as to give the most probable values of the constants. The following practical rule, the investigation of which is, we believe, originally due to Bessel, will give them:—

(153.) Suppose we have such a series of observations at epochs $\theta, 2\,\theta, 3\,\theta, \ldots\ldots n\,\theta =$ dividing any entire period into equal intervals, reckoning from and up to the end of the period, or any other convenient epoch. Let $S_1, S_2, \ldots. S_n$ be the sums of the observed values, at homonymous epochs, throughout the series. Look out, in a table of sines and cosines, for the sines and cosines of $\theta, 2\,\theta, \ldots.\, n\,\theta$ converted into degrees at the rate of 15° per hour for the diurnal, or 30° per month for the annual fluctuation (or their logarithms, if we proceed logarithmically), and call the sines in succession s_1, s_2,

.... s_n, and the cosines $c_1, c_2, \ldots c_n$, observing that $s_n = 0$ and $c_n = 1$. This done, compute the quantities a_0, a_1, ... a_n, b_1, ... b_n, by the following formulæ, in which N is the total number of observations at all the epochs.

$$a_0 = \frac{1}{N}(S_1 + S_2 + \ldots . S_n)$$

$$a_1 = \frac{2}{N}(c_1 S_1 + c_2 S_2 + \ldots . c_n S_n)$$

$$a_2 = \frac{2}{N}(c_2 S_1 + c_4 S_2 \pm \ldots . c_{2n} S_n)$$

$$a_3 = \frac{2}{N}(c_3 S_1 + c_6 S_2 + \ldots . c_{3n} S_n) \text{ \&c.}$$

$$b_1 = \frac{2}{N}(s_1 S_1 + s^2 S_2 + \ldots . s_n S_n)$$

and so on. These will be the *most probable values*, respectively, of the co-efficients in the general expression of E under the periodical form,

$$E = a_0 + a_1 . \cos. \theta + b_1 . \sin. \theta + a_2 . \cos. 2\theta + b_2 . \sin. 2\theta + \text{\&c.}$$

which may then be transformed into

$$E = a_0 + B_1 . \sin. (\theta + C_1) + B_2 . \sin. (2\theta + C_2) + \text{\&c.}$$

by taking $B = \sqrt{a_2 + b^2}$; $\tan. C = \frac{a}{b}$.

(154.) In the practical application of this formula, it is not necessary that the number of the terms of which the final result E is to consist, should be pushed farther than necessity or convenience may require, and it is a peculiarly valuable property of these expressions, that if the approximation be stopped at any one term, as, for instance, at the term $B^1 . \sin. (\theta + C_1)$, and the co-efficients B_1 and C_1 be determined accordingly, then should it be considered afterwards desirable to carry it a term farther, so as to include the next sub-period expressed by the term $B_2 . \sin. (2\theta + C_2)$, it is not necessary to recompute the former co-efficients, their values remaining unaltered, so that the several sub-periodic terms are separately and independently calculable from any *complete* series of observations, just as if the others had no existence. And moreover, the constitution of the formulæ is such that any number of complete cycles of observation may be treated as a single cycle, by taking the means of the recorded observations at homonymous epochs, and thus forming from them a single cycle.

(155.) For example, supposing we have a series of *mean monthly* results, obtained during a series of years, for any meteorological element, such as temperature, and we wish to deduce from them the law of the annual fluctuation. In the first place, we take the mean of all the results for January as a new January mean, of February for February, and so on, and denoting their means so obtained in their order, by $S_1, S_2, S_3, \ldots . S_{12}$. If we wish merely to obtain the most probable mean annual temperature, we use the expression,

$$A = \frac{1}{12}\left\{ S_1 + S_2 + \ldots . S_{12} \right\}$$

If we would now carry the inquiry one step farther, and determine the amount of fluctuation regarding the curve of temperature as one of a single undulation, neglecting subordinate flexures and sub-periods, we retain the same value of A, and calculate B_1 and C_1 by the formulæ,

$$\begin{aligned} 6\, a_1 &= (S_1 - S_5 - S_7 + S_{11}) \;.\; \cos. 30° \\ &\quad + (S_2 - S_4 - S_8 + S_{10}) \;.\; \cos. 60° \\ &\quad - S_6 + S_{12} \end{aligned}$$

$$\begin{aligned} 6\, b_1 &= (S_1 + S_5 - S_7 - S_{12}) \;.\; \sin. 30° \\ &\quad + S_2 + S_4 - S_8 - S_{10}) \;.\; \sin. 60° \\ &\quad + S_3 - S_9 \end{aligned}$$

$$B_1 = \sqrt{a_1^2 + b_1^2}; \quad \tan. C_1 = \frac{a_1}{b}$$

And if we would now go on farther to investigate the semi-annual sub-period, or that depending on $2\,\theta$, we retain the means of A, B_1, C_1, already computed, and still using the same sums S_1, S_2, &c., go on to find a_2, b_2, and from them B_2 and C_2 by the formulæ,

$$\begin{aligned} 6\, a_2 &= (S_1 - S_2 - S_4 + S_5 + S_7 - S_8 - S_{10} + S_{11}) \\ &\qquad \times \cos. 60° \\ &\quad - S^3 + S^6 - S_9 + S_{12} \\ 6\, b_2 &= (S_1 + S_2 - S_4 - S_5 + S_7 + S_8 - S_{10} - S_{11}) \\ &\qquad \times \sin. 60° \end{aligned}$$

$$B_2 = \sqrt{a_2^2 + b_2^2}; \quad \tan. C_2 = \frac{a^2}{b_2}.$$

In applying which it will be remembered, of course, that as the means S_1, S_2, &c., belong to the middle of the months, the values of θ corresponding to *them* are 30°, 60°, &c., so that the commencement of the year from which θ reckons, is, in effect, placed in the middle of December. If we reckon the time, then, from the beginning of January, this amounts to putting $\theta' + 15°$ for θ; or, retaining the same values of the co-efficients A, B_1, B_2, &c., increasing C_1 by 15°, C_2 by 30°, &c. For the third term, the co-efficients are still more simple in their expression, viz.,

$$\begin{aligned} 6\, a_3 &= - S_2 + S_4 - S_6 + S_8 - S_{10} + S_{12} \\ 6\, b_3 &= + S_1 - S_3 + S_5 - S_7 + S_9 - S_{11} \end{aligned}$$

(156.) The application of the formulæ is equally simple and easy in every other case; and, in fact, such is its facility, that it leaves no excuse to meteorologists for not reducing their observations, and should act as a powerful recommendation to induce them, in all cases, to conform to its requisitions in arranging the times of their observations.

(157.) All that depends on regular periodic action may be represented in this manner by periodic functions, the co-efficients of which, as determined by observations for any place, embody the resultant of the mode in which the action is propagated to the place. Each of them is therefore, no doubt, inherently a function of the latitude and longitude of the place, but one complicated with and dependent on the whole geographical system of the globe as one of its data — the configuration of its land, the height and arrangement of its mountain chains, nay, even the depths of its seas and the form of their beds; since all these elements enter into the list of causes which determine the arrival of heat, wind, and moisture at the place.

(158.) It is the task of the practical meteorologist, each at his own station, to furnish his quota of recorded observation towards carrying out this great work—a task tedious, perhaps, and requiring, like all scientific operations, care in observing and precision of statement, but easy in itself, and full of interest at least to such as are able and willing to execute the reduction of their own observations, and thereby to furnish (so to speak) not merely a lump of material rude from the quarry, but a stone hewn and squared on the spot, and ready to take its fitting place in the general edifice. Having fixed on the range and scope of his observations, the instruments whose indications he proposes to record, and the hours at which his personal convenience, and the dependable means at his command will enable him to record them, all he has to do is to pay scrupulous attention to obviate everything which may tend to derange the adjustment of his instruments, or affect the fairness of their exposure—to read them off accurately, and register the readings faithfully, and to adhere precisely to system in their reduction. It should be remembered, however, that no series of observations can be considered of any value for the determination of the *diurnal* co-efficients in which the twenty-four hours are not *equally* divided by the epochs of observation, and of comparatively little if they be fewer than four in number; the most advantageous hours for which, generally speaking, will be found to be 3 h. and 9 h. A.M. and P.M., or 4 h. and 10 h. A.M. and P.M., should the habits of the observer render the 3 h. A.M. observation very irksome.

(159.) To those observers, however, whose means will allow them to avail themselves of the resources which modern art affords, the principles of photographic and mechanical self-registry, which have of late been applied to all the most important instruments, affords an alleviation of all the tedium of personal attendance, and supplies what personal observation never can do — an unbroken record of the march of each instrument during the night as well as the day. On the occasion of a reward of £500, offered in 1846 by the Lords Commissioners of the Admiralty, for the discovery of an available application of photography for such purposes, two systems of procedure were devised and carried into effect by Mr Brooke and Mr Ronalds, the one at the Royal Observatory at Greenwich, the other at the observatory of the British Association at Kew, both of which have been found perfectly adequate to the object, not only of meteorological, but of magnetic self-registry. Without going into minutiæ (which the reader will find stated for the former system in the Introduction to the Greenwich Observations for 1847, and for the other in three papers published in the Transactions of the Royal Society for 1847. We may state the general principle of Mr Brooke's method in few words as follows: — Paper being prepared sufficiently sensitive to receive an impression from the light of an argand or camphine lamp by night, and the reflected light of the sky by day, is stretched between two rollers, so as to be wound on one and unwound from the other uniformly by clock-work, receiving, as it travels, punctures or marks made on it by an appropriate mechanism, at equal intervals of time, suppose hourly, and which, therefore, convert the space travelled over into a scale of time capable of being read off by a scale of equal parts, if necessary. The direction of the motion of the paper is perpendicular to that in which the indicating point of the instrument to be registered moves, whether that be the end of a column of mercury rising and falling (as in the stem of a thermometer, or in the tube of a barometer), on an index arm capable of carrying a screen pierced with a hole to transmit a small pencil of light. If the former, the light is so arranged that *only the vacant part* of the stem or tube above the mercury shall allow a free passage for it to reach the paper, the shadow of the mercury cutting off all below. If the latter, the whole paper is shaded except that point which happens at each instant to be behind the hole. In the one case, the boundary of light and shadow is marked by a curve terminating the continuous photographic impression formed by the unrolling of the paper; in the other, the impression itself takes the form of a curve line, of which the ordinate indicates the reading of the instrument at the moment of time indicated by the abscissa. To facilitate the subsequent reading off of these curves, the graduation of the scale (in the case of the thermometer), is marked on the paper by the shadows of wires carried across the stem at each degree. In Mr Ronalds' second or improved method, described in the third of the papers above cited, an image of the index point terminal line of mercury, or other object which defines the reading of the instrument, is formed by an achromatic lens on the moving paper. One or other of these systems of self-registry, or some equivalent one, is, or ought to be, adopted wherever meteorological observation is carried on as a part of the regular business of a public establishment. Taken in conjunction with the mechanical self-registry of the anemometer, and with that by which the rain-gauge is made to empty itself whenever a definite quantity of rain is collected, and to record the number of such emptyings, and the weight of water it contains at each hour, the system of self-registry may be regarded as complete.

(160.) For the special reductions which each kind of instrument requires, the nature of its adjustments, and the precautions to be observed in its use, we must refer the reader to the descriptions of the several instruments in other parts of this work under their proper heads; to the Admiralty Manual of Scientific Inquiry already referred to, and the Report of the Royal Society on the occasion of Captain Ross' Antarctic Expedition in 1840; and to the former of these works for a detail of the particulars which a complete meteorological register ought to embrace, and the most convenient and advantageous form of statement it admits.

(161.) *Of the distribution of barometric pressure, and its periodical fluctuations.*—The mean barometric pressure on any place is of course dependent on its height above the sea level, so that each locality has corresponding to it a certain individual correction or reduction to the sea level, which affects equally all its barometric observations, When the level of the place is trigonometrically ascertained, the mean temperature of the station being known, this reduction may be exactly computed; and were it a fact that the mean barometric pressure at the sea level were everywhere the same, the height of every place might be determined from the mean height of the barometer as given by observation. This, however, is not the case. We have already seen (art. 54) that in the open ocean the pressure diminishes on approaching the equator from either side, as well as the reason for this diminution. But this is not all. The atmosphere is not in a state of statical equilibrium, nor are the forms of its strata of equal density identical (as they would be in that case) with the ellipsoids of equal level, for the very obvious reason, that the surface of a fluid in motion (even when unagitated by waves), is not that of the same fluid at rest. The surface of a river, though smooth, is not a horizontal, but an inclined plane. That of a swift stream with an unequal bottom is not a plane at all, but a surface of ridges and depressions, fixed in place and permanent in form, as is seen in the familiar case of the ripple caused by a smooth round stone at some depth below the surface; hence we might be prepared to expect great differences between the surfaces of equal level and of equal density in the interior of extensive continents, where the atmosphere, swept *en masse* from the sea, up the gradual slope of the land surface, is lifted with all its strata preserving their relative bearings on each other, the extent of elevated country on all sides tending to prevent lateral overflow. Under such circumstances there may, or rather must, exist great discordances between the trigonometric and barometric determinations of altitudes (the only form in which the cause in question can make its appearance), and which, it may be remarked generally, go to render all barometric determinations uncertain in windy weather.

(162.) What may not, however, be so obvious, or rather what, when first proposed, appears quite paradoxical, is that, even in the open ocean, there exist extensive tracts in which a permanent *depression* of the barometer to the enormous extent of an inch and upwards (equivalent to an elevation of 800 feet above the sea level), is found to prevail. Such a tract is the whole extent of the Antarctic Ocean, from 63° to 74° S. lat., and 8° to 7° W. long. as ascertained by Sir James C. Ross (*Voyage of the Erebus and Terror*, ii. 376, 385); and a corresponding depression, though not to so great an extent, appears, by the observations of Ermann, to exist in the region nearly diametrically opposite, about the Sea of Ochotzk, and in the interior of the Asiatic continent of that neighbourhood.

(163.) It is impossible not to perceive, in these singular phenomena, the evidence of the existence of what must be regarded as a fixed system of ripples in the general atmosphere, caused by the great system of circulation in both hemispheres, of the trades and anti-trades reacting on the general mass of the continents as obstacles in their path, and dependent for their depths and limiting forms on the configuration of the surface of the land. The progressive change of mean atmospheric pressure at sea, in proceeding from the equator southwards, is stated by Sir J. Ross as follows:—

Lat. South.	Mean Pressure.	Lat. South.	Mean Pressure.
0° 0′	29.974	51°33′	29.497
13 0	30.016	54 26	29.347
22 17	30.085	55 52	29.360
34 48	30.023	60 0	29.114
42 53	29.950	66 0	29.078
45 0	29.664	74 0	28.928
49 8	29.469		

(164.) For northern latitudes, the results hitherto collected run very irregularly. Meteorologically, however, this is not a cause which would appear to be productive of any marked train of consequences. And in relation to the matter at present in hand, it goes only to show, that the first term of the periodic function expressing the barometric pressure, is not an absolute constant, even for the ocean, but that it has to be tabulated and worked out by local observation into a system of isobarometric lines, carried indifferently over both sea and land, and, as regards the latter, distinct from the level lines. We are far, indeed, from any approach to the construction of such a system.

(165.) The periodic fluctuations of the barometer are annual and diurnal. The consideration of the former will enable us to form a neater conception of the mode in which the latter arise. When it is summer in one hemisphere it is winter in the other. Hence (See art. 78), the air generally incumbent on the heated hemisphere is dilated, and expands both upwards and laterally, as well by its own increased elasticity as by the increased production of vapour. It therefore not only encroaches on the other hemisphere by lateral extension, but what is far more influential, flows over upon it. In order to perceive clearly the nature of the process, we must separate in idea the aqueous and aerial constituents of the portion of atmosphere so transferred. The generation of the former goes on in the heated hemisphere, and replaces, in part at least, the loss of pressure arising from the transfer of air, while in the other the excess of vapour so introduced is constantly undergoing precipitation, and is thus continually being withdrawn from the total mass, leaving behind it, however, to accumulate, the dry air which accompanied it. Thus, if we regard the total barometric pressure as subdivided into that of the dry air and of the aqueous vapour, and denote the former by P, the latter by p, we see that the dry pressure P is diminished in the hot, and increased in the cold hemisphere, without any countervailing action, while p is in process of increase from below by evaporation, and of diminution from above by overflow, in the former: and *vice versâ* in the latter. If, then, the observed barometric pressure at every point in either hemisphere be analysed by calculation into its two constituents, by taking account of the hygrometric state of the atmosphere, and subtracting from the total pressure $P+p$ the portion p due to the amount of vapour present, the remainders ought to exhibit, as a general result, an excess of dry pressure P in the winter hemisphere over that in the summer.

(166.) So far as observation has hitherto gone, this result is perfectly corroborated, though unfortunately there are not yet accumulated sufficiently numerous and extensive series of observations in which the effects of the aqueous pressure can be duly separated from the dry. As examples, we shall select the series for the Indian stations, Calcutta, Benares, Seringapatam, and Poonah, calculated by Dove from the observations of Prinsep Sparmann and Colonel Sykes, as compared with that at Apenrade from those of Neuber, and with the results obtained at the Meteorological Observatories of Prague, Toronto, and Hobart Town, V.D.L.

Stations.	P, PRESSURE OF DRY AIR.			*p*, PRESSURE OF VAPOUR.		
	Max. in	Min. in	Differ.	Max. in	Min. in	Differ.
			inches.			inches.
Calcutta,	Jan.	July	1.019	Aug.	Jan.	0.551
Benares,	Dec.	July	1.244	July	Dec.	0.645
Seringapatam,	Jan.	June	0.455	May	Jan.	0.217
Poonah,	Dec.	June	0.760	July	Dec.	0.435
Apenrade,	Feb.	July	0.450	July	Jan.	0.346
Prague,	Dec.	July	0.383	July	Jan.	0.285
Toronto,	Dec.	July	0.271	Aug.	Feb.	0.380
Hobart Town,	July	Nov.	0.218	Feb.	July	0.125

These are large quantities; but we see that as the maxima of P correspond in point of time with the minima of p, it is only their differences which constitute the total or observed annual fluctuation of barometric pressure.

(167.) Since, as observed (art. 165), the annual fluctuation of p is the result of an excess of supply over expense in one hemisphere, and of expense over supply in the other, it may very well happen that the annual fluctuation of p in certain localities may exceed that of P, and being in a contrary direction, may either neutralize the fluctuation of the gross pressure $P+p$, or convert it into one of an opposite character. This, however, is but rarely the case, and where instances of it do occur, as at Sta. Fé de Bogota, and Bangalore (*Kämtz*, ii. 299), they are for the most part readily enough accounted for by the influence of local peculiarities.

(168.) If we consider that in general the values of P and p, regarded independently, fluctuate in opposite directions, and hence the maximum of the one corresponds, or nearly so, in epoch with the minimum of the other, we shall easily see that, representing P by

$$P = A + B \,.\, \sin.\,(\Theta + C) + B' \,.\, \sin.\,(2\,\Theta + C') + \&c.,$$

we shall have, at least approximately, for p an expression such as,

$$p = a + b \,.\, \sin.\,(\Theta + C + 180^\circ) + b' \,.\, \sin.\,(2\,\Theta + c') + \&c.$$

the value of C in the term Θ differing by 180°, while those in the other terms (C', c', C'', c'', &c.) may or may not stand to each other in a similar relation—the only condition being, that they shall be such as to render the co-efficients B, B', &c., b, b', &c., all positive. The gross pressure $P + p$, then, will come to be expressed by the form,

$$P + p = (A + a) + (B - b) . \sin. (\Theta + C) + \beta . \sin. (2 \Theta + \gamma) + \beta'' . \sin. (3 \Theta + \gamma'') + \&c.,$$

Since $B' . \sin. (2 \Theta + C') + b' . \sin. (2 \Theta + c')$ may always be reduced to the form,

$$\beta . \sin. (2 \Theta + \gamma), \&c.$$

(169.) Thus we see that the tendency of the cotemporary action of the two elements composing the gross pressure is, 1*st*, to produce a mean annual pressure $(A + a)$ equal to the sum of the separate pressures; 2*dly*, to subdue the influence of the term depending on Θ, by reason of the opposition of signs affecting B and b in the joint co-efficient $B - b$; and thus, 3*dly*, to give a greater *comparative* influence to the terms depending on 2Θ, 3Θ, &c. Now it will be observed that a series thus constituted, of sines of Θ, 2Θ, &c., when made to run through its whole period by varying Θ from 0 to 360°, will have only a single maximum and minimum when the co-efficient of $\sin. (\Theta + C)$ is large in comparison with those of the other sines, but when the contrary is the case, a double, or even triple or multiple maximum and minimum may result from such mutual relations among the co-efficients as may very easily occur. The principal terms nearly neutralizing each other by their mutual opposition, leave the general character of the law of periodicity of the compound effect to be decided by the relations *inter se* of the subordinate ones, and thus is explained, without prejudice to the general reasoning in art. 77, 78 (which remains true as regards the *form* of the atmosphere as disturbed by the sun's action) the fact, which appears on first sight in opposition to that conclusion, that the annual oscillation of the gross barometric pressure presents in a great many localities the phenomenon of a double maximum, or even a still more complex character. Thus, in Paris, to take a single instance from a mean of eleven years' observations (1816–1826), the total pressure exhibits two maxima in January and in July, the former being highest, and two minima in April and October, the latter being the lowest. (*Kämtz*, ii. 295.)

(170.) The great length of time in which the efficient causes are acting in one direction, to produce the annual oscillation in question, admits of a very considerable fraction of the atmosphere to be transferred from hemisphere to hemisphere, and to allow a range in the values of P, for instance, to the large extent (as we have seen in the case of Benares) of nearly an inch and a quarter of mercury, partially neutralized by a fluctuation of more than half an inch of aqueous vapour. Thus the effects are brought out into prominence, in both elements, by the long-continued action of the causes; and thus, by the study in the first instance of the annual oscillation, we are led to an easy understanding of the perfectly analogous phenomena in the diurnal oscillations (or, as they have sometimes though very improperly been called, "atmospheric tides") which have a good deal perplexed meteorologists, but whose analysis, into what we have for convenience called wet and dry pressure, has happily been suggested by M. Dove as affording a rational explanation.

(171.) To simplify our conception of the diurnal oscillation, we will suppose the sun to have no declination, but to remain constantly vertical over the equator. The surface of the globe will then be divided into a day and a night hemisphere, separated by a great circle passing through the poles, coincident with the momentary horizon, and revolving with the sun from east to west in twenty-four hours. The contrast of the two hemispheres, both in respect of heat and evaporation, in this case will evidently be much greater than in that of art. 165, and therefore the dynamical cause, the motive force, transferring both air and vapour from the one to the other will be much greater. But on the other hand, much less time is afforded for this power to work out its full effect, and long before this can be accomplished for any locality, the circumstances are reversed, and a contrary action commences. The causes, then, and the mode of their agency, are perfectly analogous, in the production, whether of the annual or diurnal oscillation; but in the former, the feebler acting cause is aided by the very much greater length of the period; in the latter, its superior intensity is in great measure neutralized by the frequency of its reversal. There is another consideration, moreover, which cannot be without its effect in establishing a distinction between the two cases. By far the larger portion of the land is distributed over the northern hemisphere, and of the water over the southern. The former is more uniformly terrene, the latter more uniformly aquatic; and as, under the circumstances now considered, the transfer of air does not take place in the direction of meridians, but at right angles (mainly) to their direction, we should be led to expect that the amount of counteraction in the diurnal fluctuations of the dry pressure P by those of the wet p, would be, generally speaking, very different in the two hemispheres, and that therefore the extent of fluctuation in the gross pressure $P + p$ would, generally speaking, present a corresponding difference. A sufficient amount of observation has not yet been accumulated to bring this conclusion to the test of experience; but we cannot help remarking that the very same cause (the excess of water in the southern hemisphere), acting according to the difference of conditions in the case of the annual oscillation, ought to result in an average uncompensated action on the dry air, urging it towards the northern hemisphere, and to its replacement, bulk for bulk, by vapour, which being lighter than air, *may* be one of the causes of the generally lower atmospheric pressure over the Southern Ocean —a certain percentage of the due proportion of dry air being permanently driven out and prevented from returning by the constant outflow of vapour.

(172.) It ought to be observed, that the oscillations in question are only in appearance analogous to those of the oceanic tides. In the latter, the tide wave is merely a circulating form without any lateral transfer. The sun's heating action on the atmosphere is not one which, destroying a portion of its gravity, tends to alter its form of equilibrium, but one which, leaving its gravity unaltered, tends to throw its strata by their dilatation, and by the introduction of vapour from below, into forms incompatible with equilibrium, and therefore necessarily productive of lateral movements. When anemometry is further perfected, we may expect to trace the influence of this chain of causation into a morning and evening tendency of the wind (on a long average of observation), to draw towards the points of sunrise and sunset, to compensate the overflow from off the heated hemisphere, which takes place aloft in the contrary direction.

(173.) *The diurnal oscillation of the barometer* is a phenomenon which invariably makes its appearance in every part of the world *where the alternation of day and night exists*, on reducing any considerable series of hourly observations, though in extra-tropical latitudes it is for the most part so overlaid by casual variations as not to be remarked in a single day. On the other hand, between the tropics, and especially in the equatorial regions, its regularity of progress is most striking. Thus Col. Sykes remarks (*Phil. Trans.* 1850) that, among many thousand observations taken personally by himself on the plateau of the Deccan (1825-30), there *was not a solitary instance* in which the barometer was not higher at 9-10 A.M. than at sunrise, and lower at 4-5 P.M. than at 9-10 A.M., whatever the state of the weather, &c., might be. Humboldt also observes (tom. i. p. 308) :—"This regularity is such that, in the daytime especially, we may infer the hour from the height of the column of mercury without being in error on an average more than 15 or 17 min. In the torrid zone of the New Continent I have found the regularity of this ebb and flow of the aerial ocean undisturbed either by storm, tempest, rain, or earthquake, both on the coasts and at elevations of nearly 13000 English feet above the level of the sea. The amount of horary oscillation decreases from the equator to 70° N. lat., where we have very accurate observations made by Bravais at Bosekop, from 0·117 in. to 0·016 in." Within the Arctic Circle, however, the diurnal, for very obvious reasons, dies out, or rather merges in the annual oscillation.

(174.) Generally speaking, the diurnal oscillation presents the phenomenon of a double maximum. The epochs of the maxima are about 9 h. or $9\frac{1}{4}$ h. A.M., and $10\frac{1}{2}$ h. or $10\frac{3}{4}$ h. P.M., and the minima at 4 h. or $4\frac{1}{4}$ h. P.M. and 4 h. A.M. The fact that the barometer frequently, "both in summer and in winter, stands higher in the cold mornings and evenings than in the warmer midday," seems to have been first made matter of remark by Dr Beale in 1666. In 1682, Messrs Des Hayes and De Glos observed, that at Goree the barometer was usually lowest when the thermometer was highest, that it stood higher by night than by day, and that the daily depression (between the morning and evening maxima) exceeded the nightly. At Surinam the same phenomenon was noticed by an anonymous observer, and distinctly described in 1722. Towards the middle of the last century (1735-61), its existence at Quito, in the Antilles, in India, and at Sta. Fé de Bagota, was severally established by Godin. The observations of Humboldt as to the extreme regularity of its progression in equatorial America are corroborated by those of Colonel Wright in Ceylon. That the double maximum and minimum of its march really originates in almost all cases in the manner above explained, by the approximate destruction of the second term in the series

$$(A + a) + (B - b) . \sin. (\theta + C) + \beta . \sin. (2\,\theta + \gamma) + \&c.$$

owing to the opposite march of the dry and wet elements of the total pressure, has been put out of doubt by the calculations of Dove. Yet there are localities, as for instance at Bombay, in which even, in the expression of P, the co-efficient of the second term is so small in comparison with the others, as to give rise to the appearance of a double maximum in the dry pressure itself, and the mode in which this is accomplished is evidently referable to the more complicated local relations which arise from the juxta-position of land and sea under exaggerated circumstances of temperature and radiation, giving rise to alternating sea and land breezes—one minimum of the dry pressure being found to coincide with the greatest strength of the sea breeze, the other with that of the land breeze, and the maxima with the minima of force of the wind.

(175.) If we regard only the gross pressure $P + p$, the following table will exhibit the amount of its daily fluctuations above and below the mean value, as deduced from the calculations of Kämtz (ii. 254, &c.)—

PLACE.	Latitude.	Morning Min.	Forenoon Max.	Afternoon Min.	Evening Max.
		in.	in.	in.	in.
Atlantic Ocean	0° 0′	—0.056	+0.069	—0.045	+0.045
Pacific Ocean	0 0	—0.032	0.040	0.045	0.028
Payta . . .	5 6 S.	+0.004	0.051	0.082	0.050
Sierra Leone	8 30 N.	—0.022	0.032	0.038	0.031
Cumana . .	10 28 N.	0.022	0.043	0.050	0.037
La Guayra .	10 36 N.	0.023	0.054	0.048	0.029
Callao . . .	12 3 S.	0.038	0.045	0.044	0.035
Lima . . .	12 3 S.	0.071	0.065	0.067	0.050
Pacific Ocean	16 0 S.	0.021	0.040	0.040	0.028
Otaheite . .	17 29 S.	0.035	0.052	0.030	0.018
Pacific Ocean	18 0 N.	0.020	0.034	0.044	0.027
Calcutta . .	22 35 N.	0.017	0.052	0.038	0.018
Rio Janeiro .	22 54 S.	0.036	0.040	0 040	0.030
Cairo . . .	30 2 N.	0.008	0.035	0.055	0.030
Padua . . .	45 24 N.	0.004	0.012	0.014	0.007
Munich . .	48 8 N.	0.011	0.011	0.008	0.009
Halle . . .	51 29 N.	0.006	0.013	0.012	0.005
Abo . . .	60 57 N.	0.009	0.002	0.005	0.008

(176.) As examples of the application of the general form of expression in cosines of the sun's hour angle from noon, we shall subjoin only the values obtained by Kämtz by the method of least squares from the whole series of observations recorded for three of the above localities, viz., Payta, Callao, and Padua.

For Payta.

$$P + p = 29^{\text{in.}}\cdot840 + 0^{\text{in.}}\cdot050\ .\ \sin. (\theta + 203^\circ\ 2') + 0^{\text{in.}}\cdot037\ .\ \sin. (2\,\theta + 153^\circ\ 43').$$

For Callao.

$$P + p = 29^{\text{in.}}\cdot824 + 0^{\text{in.}}\cdot099\ .\ \sin. (\theta + 180^\circ\ 59') + 0^{\text{in.}}\cdot036\ .\ \sin. (2\,\theta + 171^\circ\ 6').$$

For Padua.

$$P + p = 29^{\text{in.}}\cdot797 + 0^{\text{in.}}\cdot005\ .\ \sin. (\theta + 183^\circ\ 46')\ 0^{\text{in.}}\cdot010\ .\ \sin. (2\,\theta + 135^\circ\ 59')$$

(177.) The stations in the foregoing table are (except in the cases of Munich, Halle, and Abo) at the sea level. On mountain stations, or at least on such as rise abruptly from that level, or from an extensive plain, there exists a cause of diurnal oscillation in the barometric pressure of quite a different nature from that above considered. The whole vertical column of air, from the sea level to the top of the atmosphere, being dilated by the increase of diurnal temperature, it is evident that in the hotter portion of the twenty-four hours, a certain portion of the air below the cistern of the barometer must be lifted above it, and *vice versâ* for the colder. The actual weight of air incumbent on the mercury must thus be alternately varied in excess and defect of its mean amount, and the mercurial column balancing it must rise and fall accordingly. The effect of this cause (which runs counter to the law of oscillation of the dry air at the sea level, though forming part and parcel of the mechanism by which that law is determined), is easily calculable for any given elevation and diurnal change of temperature. Supposing that of the whole aerial column between the sea and the station uniform, and equal to the mean of the upper and lower, it is easily shown that the effect in question will attain its maximum value at an altitude where the barometric pressure is one 2·7182818th of that at the sea level, *i. e.* $11^{\text{in.}}\cdot03$, corresponding to about 26100 feet, and at this height the total diurnal fluctuation due to a change of temperature of 30° Fahr. would amount to the very considerable quantity $0^{\text{in.}}\cdot672$. The effect at inferior elevations for 10° of diurnal oscillation of temperature is calculated in the following table:—

Alt. in Feet.	Diurnal Oscillation for 10° F.	Alt. in Feet.	Diurnal Oscillation for 10° F.	Alt. in Feet.	Diurnal Oscillation for 10° F.
	inches.		inches.		inches.
1000	0.022	6000	0.111	11.000	0.168
2000	0.043	7000	0.125	12.000	0.176
3000	0.062	8000	0.137	13.000	0.184
4000	0.080	9000	0.148	14.000	0.191
5000	0.096	10000	0.159	15.000	0.197

These quantities, when increased in the ratio of the actual diurnal changes of temperature, are quite large enough at any considerable elevation to overlay and mask the real diurnal oscillation, and ought therefore to be applied as a reduction to the sea level, whenever local circumstances are such as to render such reduction safe and possible, which is not often the case.

(178.) *Diurnal and annual fluctuations of temperature, and climatological distribution of heat.*—We have seen (arts. 11, 107) that moisture in the form of visible clouds, or even in that *excessively divided, yet unevaporated state* which is sufficient to injure the transparency of the atmosphere, and which must be confessed to belong to the yet unresolved problems of meteorology, produces absorption of the sun's rays, and the conversion of sensible into latent heat. The diurnal march of temperature, then, in the general atmosphere is intimately connected with its hygrometric state, and especially with its degree of *relative* dryness, *i.e.*, its more or less near approximation to a state of saturation; and for the same reason that the heat of the day is mitigated by the evaporation of the diffused moisture, so is also the cold of night by its deposition, and hence arises a phenomenon of very general prevalence, viz., that the difference between the daily and nightly extremes of temperature, or the extent of its diurnal fluctuations, is greater in summer than in the winter, or rather to speak more generally, and in language applicable alike to inter and extra tropical localities, in those seasons where the air is *relatively drier* or *moister*. In fact, it is evident that when the air is relatively dry, evaporation during the day is more active and a larger portion of the incident heat becomes latent; and on the other hand, that as it is necessarily the dew-point which limits (at least approximately) the temperature of the lowest stratum of air at night (see art. 45), since in the act of condensation the vapour gives out its latent heat, and therefore so long as the supply is continued prevents its further depression, the farther removed from saturation the air is, the greater depression can be effected by radiation before that limit is reached. The near coincidence of the dew-point with the lowest nightly temperature, at every season of the year, has been shown by Anderson from observations made at Kinfauns Castle during the year 1815, and the calculations of Kämtz show that the difference between the daily extremes of temperature is universally greatest in those months of the year when the relative dryness of the air is the greatest.

(179.) In India, again, where, properly speaking, there cannot be said to exist a winter, the moist and cloudy season is that in which the least diurnal fluctuation of temperature occurs—a circumstance sufficient of itself to show that it is not to the difference in the lengths of day and night, or to the low altitude of the sun in winter that the phenomenon in higher latitudes must be attributed, since between the tropics these causes can have but little influence. The east and west coasts of Ceylon exhibit in this respect a pointed contrast. At Colombo, on the western side of the island, the least diurnal change of temperature takes place in July, and the greatest in January, the rainy season being that of the SW. monsoon, when the sun is north of the equator; while at Trincomalee, on the eastern side, the reversed conditions as to moisture obtain, accompanied with a corresponding reversal in the extremes of temperature.

(180.) The uniformity of temperature which prevails at sea, and the greater general uniformity of an insular as contrasted with a continental climate, has already been noticed (art. 40), and is at least partly referable to the same cause, viz., the alternate conversion of sensible into latent heat, and *vice versa*, by the evaporation and condensation of moisture disseminated through the atmosphere during day and night, in addition to the causes there enumerated. In consequence, in the neighbourhood of the sea, on an average of the whole year, the twenty-four hours are unequally divided into the hotter and the colder portions; that is to say, those in which the temperature is above, and in which below the mean—the comparative shortness of the hotter portion being compensated by a greater absolute elevation of temperature, and the length of the colder by a less absolute depression.

(181.) The foregoing considerations sufficiently show how vain would be any attempt to conclude even an average of the progression of daily temperature, *a priori* setting out with a knowledge of the declination of the sun and the latitude of the place, and thence calculating the amount of heat received even in a calm atmosphere. Observation only can lead to any just conclusion, and the general process indicated in art. 150 must be resorted to, leaving to subsequent theoretical enquiry the difficult (indeed at present impracticable) task of assigning to direct solar and terrestrial radiation, moisture, and wind, their share in producing the final result. As instances, however, of the kind of results which are attainable in this direction, we shall here set down the formulæ for the mean diurnal temperature, calculated by Kämtz from the hourly observations of Chiminello at Padua, and those instituted by Sir David Brewster, at Fort Leith, near Edinburgh, viz., for Padua—

$$T = 56^\circ.75 + 4^\circ.79 \sin. (\theta + 51^\circ.47') + 1^\circ.00 \sin. (2\,\theta + 66^\circ.33') + 0^\circ.22 \sin. (3\,\theta + 233^\circ)$$

and for Fort Leith—

$$T = 48^\circ.24 + 3^\circ.03 \sin. (\theta + 44^\circ.43') + 0^\circ.43 \sin. (2\,\theta + 44^\circ.43') + 0^\circ.14 \,. \sin. (3\,\theta + 175^\circ.11').$$

(182.) It is a matter of much importance, in cases where a complete and continued series of meteorological observations cannot be obtained, and in sea voyages, where no lengthened stay is made at any one place, to ascertain the mean temperature approximately from the least possible number of observations. This may be accomplished in different ways, viz.—1*st*, By taking care to observe at those hours, or one of them in which the temperature is habitually, exactly, or very near its mean through the twenty-four hours, or at such hours as shall have the mean of their temperatures very nearly coincident with that of the day. Such hours are 4 A.M. and 4 P.M., or more conveniently 10 A.M. and 10 P.M. If four observations *per diem* can be made, these four epochs should be chosen in preference. 2*dly*, By taking the mean of the maximum and minimum for the mean temperature. This, however, is a coarse and rude approximation, as is obvious on considering what has been above stated, art. 180, as to the greater length of time during which, at stations near the sea, and still more at sea, the temperature ranges below the mean than above it. Kämtz recommends (from a discussion of the observations at

Padua and Fort Leith above mentioned) to employ the formula $m+\frac{\mathrm{M}-m}{36}(5{\cdot}076+x)$ where x is a variable co-efficient, fluctuating from 0·366 in December to 0.560 in August; and which may, for the purpose in question, be taken quite near enough at 0.44 . sin (Θ + 120°), Θ being sun's mean longitude. The mean temperature of the day may also be very approximately obtained from three temperatures t, t', t'', observed at 7 A.M., 2 P.M., and 9 P.M., by the formula

$$\frac{t+t'+2\,t''}{4}$$

or if observed at 8 A. M., 3 P. M., and 10 P. M., from the expression

$$\frac{7\,t+7\,t'+10\,t''}{24}$$

(183.) The annual fluctuation of temperature is derived from the consideration of the consecutive values of the mean temperatures of each day, or of the constant co-efficient A in the expression of the diurnal temperatures, considered as a periodical function of Θ, the sun's mean longitude; or, if we please, of θ, the arc proportional to the time commencing from any given date. For simplicity we shall suppose, however, that the value $\theta=0$ commences on the 1st of January, so that $\theta=15°$ corresponds to the middle of January, 45° to that of February, &c., or rather to the exact days nearest the middle of each month, which divide the year into 12 equal parts. The monthly mean of temperature being obtained by taking the arithmetical means of the daily ones for each month, the annual formula

$$\mathrm{T}=a+b_1\,.\,\sin.\,(\theta+c_1)+b_2\,.\,\sin.\,(2\,\theta+c_2)+\&c.,$$

will be obtained, as in art. 155. The following values for a series of stations in order of latitude calculated by Kämtz, will serve as examples for extra-tropical latitudes :—

Place of Observation.	Latitude.	Value of A deg. Fahr.	Value of B.	Value of C.	Value of B′	Value of C′	Hottest Day.	Coldest Day.
Enontekies . .	68°40′ N.	26°.85 F.	23.93	266°59′	1.92	404°21′	July 26.	Jan. 20.
Upsal, . . .	59 48 N.	41 .70	19.77	266 23	1.07	420 15	July 21:	Jan. 16.
Christiania, . .	59 54 N.	41 .60	19.15	264 26	2.13	434 29	July 20.	Jan. 17.
Manchester, . .	53 29 N.	47 .66	12.09	264 46	0.98	372 32	July 27.	Jan. 12.
Paris, . . .	48 50 N.	51 .44	14.48	266 13	1.39	344 31	July 28.	Jan. 15.
Padua, . . .	45 25 N.	54 .21	21.03	260 52	1.15	381 17	July 26.	Jan. 15.
Turin, . . .	45 5 N.	53 .00	20.08	267 41	1.81	343 41	July 27.	Jan. 5.
Fort Sullivan, . .	44 0 N.	41 .81	20.59	258 31	0.49	361 3	July 29.	Jan. 24.
Rome, . . .	41 54 N.	59 .87	14.64	260 21	1.23	386 14	Aug. 1.	Jan. 16.
Fort Johnston, . .	34 0 N.	66 .60	15.19	265 31	0.49	408 20	July 21.	Jan. 18.
Cape Town, . .	33 52 S.	66 .49	8.72	$\left\{\begin{matrix}264\ 38\\-180\end{matrix}\right\}$	1.28	357 43	Jan. 6.	Aug. 4.
Abusheher, . .	28 15 N.	77 .06	16.89	262 47	1.57	352 20	July 18.	Jan. 12.

To which, as a further example, we shall add the expression of the annual variation of temperature at St. Petersburg, from the *Correspondance Meteorologique* of M. Kupffer, 1848, where the terms beyond the 3d order, though given in the original, are suppressed as insignificant, viz.—

$$\begin{aligned}\mathrm{T}=38°{\cdot}73+23°{\cdot}32\,.\,\sin.\ &(\theta+263°\ 42')\\+\ 0°{\cdot}89\,.\,\sin.\ &(2\theta+115°\ 27')\\+\ 0°{\cdot}39\,.\,\sin.\ &(3\theta+234°\ 31')\end{aligned}$$

(184.) The general *coup-d'œil* of the annual progression of temperature afforded by these results is not a little remarkable. The values of C, upon which the epochs of the maximum and minimum and mean temperature mainly depend, are very nearly alike, and have but little reference to the latitude of the place, and as we see the epochs set down (those for Cape Town, whose latitude is south being reversed), all agree in placing the extreme of heat and cold nearly about the 26th July and the 14th January. The epochs of the mean computed from the formulæ offer a similar agreement; all fall within a very few days of the 24th April and 21st October. A general mean of the whole, which may be taken as a very near approximation to the law of annual temperature over at least the whole of the extra-tropical northern hemisphere, and probably also of the southern, may be expressed thus :—

$$\begin{aligned}\mathrm{T}=\mathrm{A}+\tfrac{1}{2}\,(\mathrm{M}-m)\,.\,\sin.\,(\theta+263°\ 54')\\+\tfrac{1}{30}\,\mathrm{M}-m)\,.\,\sin.\,(2\,\theta+23°\ 46')\end{aligned}$$

Where M and m are the maximum and minimum respectively of the mean diurnal temperatures (*Kämtz*, i. 126). As the co-efficient of the second term is 1-15th that of the first, which is the precise fraction by which the intensity of solar radiation fluctuates by reason of the change of the sun's distance—this might almost lead to a surmise, that the semi-annual term has its origin in this cause (since it is obvious that it cannot have a purely local origin.) In effect, if we consider the simple expression, $\mathrm{T}=\mathrm{A}+\mathrm{B}\,.\,\sin.\ (\theta+\mathrm{C})$, as varied by regarding A and B (which are evidently proportional, *cæteris paribus*, to the force of direct solar radiation) each to be variable by reason of the varying proximity of the sun, and to be represented respectively in general by $\mathrm{A}+a\,.\,\sin.\ (\theta+\alpha)$ and $\mathrm{B}+b\ .\ \sin.\ (\theta+\beta)$; A and β being still the *mean* values of these co-efficients in a whole revolution, the expression for T will become

$$\mathrm{A}+a\,.\sin.(\theta+\alpha)+\mathrm{B}\,.\sin.(\theta+\mathrm{C})+b\,.\sin.(\theta+\beta).\sin.(\theta+\mathrm{C})$$

which is reducible to the form

$$\mathrm{M}+\mathrm{N}\,.\,\sin.\,(\theta+n)+\frac{b}{2}\,.\,\sin.\,(2\,\theta+p),$$

M, N, P, n, p, being constants. This cause, then, would in fact introduce a term depending on $2\,\theta$, or having a semi-annual period, into the ultimate effect of the sun, and proportional to the eccentricity of the earth's orbit. We are quite ready to admit that this reasoning is not very strict, but the coincidence is a remarkable one, and it is rather thrown out as a surmise than as a demonstration.

(185.) Between the tropics, however, other and powerful causes, having obvious reference to geographical situation, tend to increase the semi-annual term, depending on $2\,\theta$, and by rendering it more nearly comparable to that depending on θ, disturb the regular increase and decrease in a very marked manner. Not only does the sun between the tropics pass twice a year through the zenith of each station, but the interception of his beams by cloud during the afternoon at least of almost every day in the wet season, the descent of a large quantity of cold rain from the upper regions of the air, and its evaporation from a heated soil, all go to disturb the simple law of increase and diminution of heat with the sun's meridian altitude and the length of the days, which moreover vary but little in these regions. Owing to these causes, then, the heat in those regions near the tropics where a rainy monsoon prevails, instead of continuing to increase as the sun becomes more nearly vertical, so as to produce a burning summer, remains nearly stationary, and even in some localities undergoes a slight depression, thus producing a double minimum with the progress of the rains, while in others, where this cause does not act, no such duplication takes place.

(186.) To determine with precision the mean annual temperature of a place requires the accumulation of many years' observation. This is abundantly shown by comparing the results obtained in successive years for a long period, wherever records exist of a dependable character, which can hardly be said to be the case, however, earlier than the year 1770, owing not only to absence of due care in ascertaining the zero points, and verifying the scales of thermometers, but also to the want of sufficient attention to circumstances of exposure, &c. Where, however, such records do exist, it is found that differences to the extent of two or three degrees of Fahrenheit in the means for individual years from a general mean of the whole occur. Thus in a series of annual temperatures deduced by Mr Glaisher from the records kept at the Royal Observatory at Greenwich, during the 85 years elapsed from 1771 to 1855 (both included), we find the extremes of cold and hot years to be respectively 51°.3 and 45°.1, differing by 6°.2 *inter se*, and 3°.1 each from the general average. So also in the series of mean temperatures for Manchester for 25 years from 1794 to 1818, derived by Dalton, we find a variation of 5° F. in hot and cold years; and in a similar series for Paris, as deduced by Bouvard from the records of the Observatory of that city for 21 years, nearly as much. Such differences might be expected when we consider the exceedingly variable influence of winds and cloudy and rainy seasons; and the differences, moreover, from year to year, succeed each other with great irregularity, so that it becomes exceedingly difficult to form any judgment as to the existence of a law of periodicity in this respect. The observations of Mr Luke Howard, indeed, in the neighbourhood of London, have led him to suspect a decennial period of fluctuation; and the records of the Greenwich Observatory above mentioned show a marked tendency to a regular increase and diminution, with a period of 14 years from minimum to minimum; but these two results partly contradict each other, and, so far as other similar records have been examined, no distinct conclusion on the subject would appear to have been arrived at. We shall not long, however, remain in ignorance on this point. Multiplication of stations, in which normally accurate observations are made, will furnish data in 15 or 20 years fully competent to decide the question; since any cause of a general or astronomical nature (such as that alluded to in art. 7) must of necessity make its appearance on the comparison of a great many stations, in the lapse of a single period, quite as evidently, indeed more so, than at one and the same station in the lapse of many.

(187.) As the mean annual temperature at any place is a very important element in its climatological relations, it is desirable to point out means by which it may be obtained with the least possible amount of observation and registry by residents whose avocations will not allow them to perform a complete series of meteorological observation. From what has been said (art. 184), it will easily be collected that from observations of the daily temperature from a week before to a week after the 24th April and the 21st October, in any part of the world beyond the tropics, will afford a certain approximation to the temperature in question; so will also a mean between the extreme temperatures (similarly observed at about epochs of maximum and minimum, January 14 and July 26.) Another method consists in deadening and weakening the effect of casual diurnal fluctuation by recording twice in the 24 hours, at 12 hours' interval, the readings of a thermometer with a long stem, having the bulb and lower part of the stem packed in a tin box of dry sand or saw-dust, but otherwise fairly exposed. A few days' attention to such a thermometer will show at what interval beyond the hottest and coldest times of the day its indications attain their maxima and minima, the means of which will give very nearly indeed the mean diurnal temperatures. The enclosure of a maximum and a minimum self-registering thermometer in a large cask of dry sand, which might be opened and read off twice a year, would also probably afford a very accurate mean result.

(188.) From what is said in art. 39, it is evident that the temperature of the soil at some considerable depth below the surface will never vary greatly from the mean annual temperature of the air, and that therefore the temperature of the last-drawn portions of large quantities of water, freshly drawn from deep, closed wells, or that of copious perennial springs which there is reason to believe do not rise from any very great depths (and so bring up the higher temperature of the interior of the earth), or descend from much higher land in the neighbourhood, will also afford a considerable approximation. At four feet deep, the mean temperature of the soil in extra-tropical regions may be considered as attained about the 10th of June and the 6th of December, at which times, therefore, its observation will give nearly the yearly mean temperature. Boussingault states that under the equator it is sufficient to observe the temperature of the soil at that or even a less depth, at any time, to obtain a very near approximation to this element.

(189.) As this element of all other meteorological data is that which it is desirable to obtain with the greatest precision, it is necessary to be on our guard against receiving, as final, results so obtained. The temperature of the soil is necessarily influenced by that of copious rain, which brings with it the temperature of the upper strata of the atmosphere, and carries it rapidly down below the surface, in a very different manner from that of sunshine, nocturnal radiation, or aerial conduction. Where the rains are distributed with tolerable equality over the year, the aberration of the mean temperature of the soil from that of the air from this cause is not likely to be material. But it is otherwise where the reverse of this condition prevails. Thus Smith found, in Congo, the temperature of a well 100 feet deep 73° F., being 5° below the mean temperature of the place of observation. Again, when the earth is long covered with snow, which during its melting preserves a uniform temperature of 32°, and while unmelted, greatly impedes the free communication of heat between the air and the earth, it cannot be that the same law of the downward propagation of temperature should be followed as if the same amount of water had fallen in a liquid form. M. Kupffer has constructed a series of lines analogous to Humboldt's isothermal lines, which he terms isogeothermal lines, and which connect the points at which the mean temperature of the soil is constant, thus forming a series of curves for 0°, 5°, 10°, ... as far as 25° Cent. These are by no means coincident with the isothermal lines of the same temperatures. Thus, for instance, the two curves for 10° C., which coincide over the southern part of England, begin to diverge where they enter on the continent of Europe,

—the isogeothermal curve deviating northwards in its eastern progress, until at a point in Asia, about half way between the Baikal Lake and the Caspian Sea (see the chart, Pl. CLXXIII.) (or in lat. 50°, long. 80° E.) it meets the isotherm of 5° C., thus indicating a difference of 5° C = 9° F. between the air and soil; and again, at a point north-east of Petersburg, in lat. about 63°, long. 40° E., a similar encounter between the isotherm of 0° (32° F.) and the isogeotherm of 5° (41° F.) takes place.[1] It is probable, however, that in most places where the soil is porous or gravelly, and where well-water is not found but at some considerable depth, the temperature of the soil at three or four feet deep under an area extensively roofed over and well drained around, and where no artificial temperature is kept up (and in cities many such may be found), a very exact annual temperature might be obtained.

(190.) But it is rather to careful observations of the temperature of the equatorial seas (according to a suggestion of Arago) at a few feet below the surface that we should look for normal results, capable of being compared from year to year with a view to bring into view any secular or periodic change of mean annual temperature. There are vast regions of the Pacific where, "over thousands of square miles, a wonderful uniformity of temperature prevails," and where both the diurnal and annual fluctuations are reduced within exceedingly narrow limits. In these, therefore, the accumulation of observations during voyages made with instruments *really* dependable, and executed with *really* scientific precautions, would very soon put us in possession of some decisive conclusion on this most interesting point.

(191.) The influence of the alternate annual approach and recess of the sun, consequent on the eccentricity of the earth's orbit, to produce an annual fluctuation of the *mean temperature of the whole earth*, has been shown in art. 12 to be *nil*. But Prof. Dove has shown, by taking at all seasons the mean of the temperatures of points on its surface diametrically opposite to each other, that the *average temperature of the whole earth's surface* in June considerably exceeds that in December. This is owing to the great excess of land in the northern and of water in the southern hemisphere, which gives to the general climate of the former more the character of a continental, to the latter more that of an insular or oceanic one (art. 40). Suppose A and a to be the summer and winter average temperatures in the former, and B and b in the latter. Then the summer falling in June in the northern, and in December in the southern, the June temperatures in both will be A, b, and their mean, or the average June temperature of the whole earth, $\frac{A+b}{2}$. Similarly the average December temperature will be $\frac{a+B}{2}$, and the difference, or (June—December) will be $\frac{A+b}{2}-\frac{a+B}{2}=\frac{A-a}{2}-\frac{B-b}{2}$, which is a positive quantity, because the fluctuation $A-a$ is (for the reason assigned) greater than $B-b$.

(192.) The best general idea of the distribution of heat over the globe is to be gathered from a chart of the isothermal lines; and as the limits of this article forbid our entering into any detailed account of a subject which properly belongs rather to the department of physical geography, we shall content ourselves with referring to that given in Plate CLXXIII., in which we find these lines already laid down on Mercator's projection, and to that given with less precision and in less detail, but conveying a clearer notion of their forms in high latitudes in the polar projection, Plate CLXXIV., and to the description of them under the head of CLIMATE, observing only that in the latter, one point only of maximum cold ($3\frac{1}{2}$° F.), that namely in the neighbourhood of Melville Island, is laid down, whereas the existence of a second point of even lower mean temperature (2° F.) appears to be sufficiently well established somewhere about the 79th degree of north lat., long. 120° east (which is accordingly duly projected on the other chart). The curves, accordingly, about the north pole bear no inapt resemblance (as remarked by Sir David Brewster) to the isochromatic lines, or coloured sphæro-lemniscates exhibited by polarized lights in a biaxal crystal, whose optic axes are inclined to each other about 30°, having the pole itself almost centrally situated between them, and their line of junction nearly coincident with that diameter of the polar basin which bisects it and passes through its two great outlets into the Pacific and Atlantic Oceans—a most remarkable feature, strongly indicative of the absence of land, and of the prevalence of a materially milder temperature (possibly not averaging below 15° F.) at the actual pole. Of the point or points of maximum cold in the southern hemisphere we know nothing.

(193.) The general equation of the optical curves in question is,

$$\sin.\theta.\sin.\theta'=T.$$

T being a number expressing what is called in optical language the *order* of the tint exhibited (and which varies in arithmetical progression, on passing from one curve to another in succession of the same colour) and θ, θ' the distances of any point in one and the same curve from the two poles respectively. Thus in fig. 7, S and S′ being the poles, P the middle point between them, A B C D the *optic equator* of the polarizing crystal, A P C, D P B meridians, the one passing through S S′, the other at right angles to it, and M N any one of the isochromatic curves of the order T, we shall have $SM=\theta$, $S'M=\theta'$. There can be no doubt then, from the general resemblance of the two sets of curves, that supposing a mean temperature thermometrically indicated by T to prevail at any point, M, in north latitude, a curve K L M N O traced by calculation from the equation $a.\sin.\theta.\sin.\theta'=T-\tau$ (a being some certain numerical constant independent of t), would approximate at least in some rude and general way to the isothermal line corresponding to T. Suppose this done for temperatures varying by *equal thermometric intervals* and a series of curves so drawn. It is obvious, then, that these curves, in respect of their magnitudes, distances from their foci and the pole P, as well as

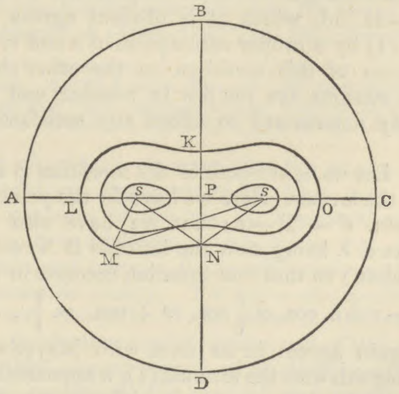

Fig. 7.

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[1] We are bound to state what we find recorded, but we must confess that such results appear to us incredible.

in their general gradations of flexure, will coincide, or nearly so, with a series of isochromatic curves *equidistant in their orders of tint*. Now, this latter series will divide the meridians B P D and A P C, in a succession of points distributed over them, not at equal differences of distance from the pole P, nor alike in the two meridians, but following a certain law of progression in each. Let us enquire what this law is; and to begin with the meridian P D, passing through the poles:—Take $\lambda = \mathrm{A\,L}$, the latitude of L, then, for the values of θ, θ' corresponding to the point L, we have $\theta = 90^\circ - (c + \lambda)$ and $\theta' = 90^\circ - (c - \lambda)$, and therefore

$$\mathrm{T} - \tau = \sin.\,\theta\,.\,\sin.\,\theta' = \cos.\,(c + \lambda).\,\cos.\,(c - \lambda)$$
$$= \frac{a}{2}\left\{\cos.\,2\,c + \cos.\,2\,\lambda\right\}$$

or, which comes to the same thing, putting $\gamma = 90 - c$ ($= 75^\circ$, since $c = 15^\circ$ or thereabouts.)

$$\mathrm{T} - \tau = a(\cos.\,\lambda - \cos.\,\gamma^2)\ .\ .\ .\ (1)$$

Now it is remarkable that this is precisely the form in which Mayer endeavoured to express empirically the decrement of temperature in proceeding from the equator towards the pole, from such observations as could be obtained about the middle of the last century, and which has been adopted by Kirwan and most other meteorologists since his time with various more or less successful attempts to assign values to the constants a and $a\,.\cos.\,\gamma$ (regarded as a single co-efficient). M. Kämtz, who has taken vast pains to combine by the method of least squares, the mean temperatures on different meridians, so as to afford the most probable value of the co-efficient of Mayer's formula $a\,.\cos.\,\lambda^2 + \beta$, assigns for the meridian now under discussion, running from Melville Island through the interior of the American continent, as the centigrade reading of the mean temperature $\mathrm{T} = 56^\circ{\cdot}77 \times \cos.\,\lambda^2 - 21^\circ.56$, which it is obvious agrees with our equation (1) by a proper assumption of a and τ. On the prolongation of this meridian on the other side of the pole, the stations are too few in number and probably too loosely determined to afford any satisfactory comparison.

(194.) Let us next consider the meridian B D at right angles to the former. Here we have for the point N, $\theta = \theta'$, and $a\,.\sin.\,\theta^2 = \mathrm{T} - t$; but we have also $\cos.\,\theta = \sin.\,\lambda\,.\,\cos.\,c$, λ being now the latitude B N reckoned on this meridian; so that our equation becomes in this case,

$$\mathrm{T} - \tau = a.\cos.\,c^2\left\{\cos.\,\lambda^2 + \tan.\,c^2.\right\}\ .\ .\ (2)$$

which again agrees in its form with Mayer's formula. Comparing this with the formula (1), it appears that the coefficients of $\cos.\,\lambda^2$ in the two meridians are to each other in the proportion of $1 : \cos.\,c^2$, or about 100:93. The mean of the results obtained by Kämtz *in the northern portions* of the Atlantic and Pacific Oceans, compared with that similarly derived for the opposite meridian, gives 100 : 69 for the same ratio, which at least is so far satisfactory in the way of agreement, that the difference lies in the right direction. It will, of course, be understood that we have not the smallest intention of tracing any *physical* analogy between the two sets of curves, our only object being to point out the coincidence between them (which we do not remember to have seen before noticed), in respect of the arithmetical progression of temperature in the one series corresponding to that of chromatic sequence in the other, as something different from and additional to a mere general resemblance of form.

(195.) Another consequence of the general causes pointed out in arts. 37, 38 of the different habitudes of land and water as regards their reception and retention of heat, is the general law which appears to prevail in respect of the comparative severity of the winters and heat of the summers in the interior of the great continents of the northern hemisphere and on their coasts, and of the general mildness of climate on west coasts as compared with east, in the extra-tropical latitudes. The former is a very obvious result, and is strongly exemplified in the interior of Russian Asia. Thus Tobolsk, Barnaoul, and Irkutsk, with summers in which the thermometer for weeks together attains 86° or 88° F., have winters in which the *mean* temperatures are from —0° to + 4° F. Thus, too, at Astrachan, the mean summer temperature averages 70° F., allowing the production of the most magnificent grapes in the open air, with a mean annual temperature of only 48°, that of London. At Kislar, at the mouth of the Terek, in 44° N. latitude, that of the south of France, the thermometer sometimes falls in winter to—22° F. It is to Leopold Van Buch that we owe the first notice of this remarkable contrast of climates, the subject of which has been extensively pursued by Humboldt, Schouw, and others. The other consequence is not so obvious. Where the prevalent winds (the anti-trades) blow from the south-west, they carry with them an oceanic temperature and an abundant supply of vapour (which, as we have seen, tends to equalize the extremes of temperature) to coasts having a westerly exposure, while, on the other hand, the same winds arriving on eastern coasts after passing over extensive continents, propagate forwards in that direction the extreme climates of their interior. Again, those winds which are incident on eastern coasts from the seaward side, having mainly a north-eastern character, bring with them the cold of a higher latitude. This latter effect is strongly felt on the east coast of our island, while the extreme mildness of the west coast of Ireland and the north-west coast of Scotland equally testifies to the powerful influence of the there prevalent south-westerly winds.

(196.) Before quitting the subject of temperature and its variations, we must notice a conclusion which has been supposed to be obtained by dividing the year into penthemers or portions of five days each (with one of six in leap years), and calculating from extensive series of observations the mean temperature of each penthemer. This task has been executed by Ofverbom for a series of fifty years' observations taken at the Observatory of the Academy of Sciences at Stockholm, and by Brandes for a great many other European stations from Petersburg to Rome. The results go to indicate two rather remarkable *hesitations*, or even slight retrogressions in the generally regular increment of temperature from winter to summer, viz., one about the 12th of February, the other between the 4th and 14th of March, the date being later as the station lies more to the south. Both would seem to be attributable rather to northerly or north-easterly winds setting in about those dates than to any general cause, though some speculations would go to assign them a very remote origin, and even to trace them up to a periodical partial obscuration of the sun by flights of meteors (!)

(197.) *Of the periodical fluctuations in the hygrometric state of the atmosphere, and of the distribution of aqueous vapour on a large scale.*—With exception of a few very limited regions in which fogs are habitually prevalent, and certain points here and there occurring in which rain is almost constantly falling, the general state of the atmosphere is one of more or less hygrometric dryness, so that, as a rule, evaporation may be considered as going on continually over the whole surface of the globe, being only interrupted where that surface is during certain hours of the night cooled by radiation below the dew-point. During these, the earth is actually abstracting moisture from the air, at all other times supplying it; but far more copiously during the day than the night. Meanwhile, the very highest regions of the atmosphere being from time to time drained of their moisture by precipitation, there is always a demand for vapour upwards, which (in the view we have taken of cloud, art. 107) is no way intercepted in its ascent by the existence of a region where it assumes for a while a visible form, and which can only be looked upon as a temporary halting place, the upper surface of the cloud evaporating while the cloud itself is renewed by condensation of the ascending vapour at the lower; unless, indeed, the radiation from the cloud itself should for a time so far lower its temperature as to suspend for a while or even reverse the process. (See art. 95.)

(198.) At the epoch of maximum cold, when the surface of the earth is at or near the dew-point, the hygrometric state of the air, to a considerable altitude, is near saturation, and frequently either a stratus cloud rests on the ground or exists at a much lower altitude than in the day, and when this is not the case, still the whole column of air, by reason of the general depression of temperature, is much nearer to its point of saturation than in the day time.

(199.) It is the practice of meteorologists to designate by the expression "humidity of the air," the degree of its approach to complete saturation with vapour, and to give precision to this language by attributing to that degree a numerical value, viz., the ratio of the quantity of vapour actually present per cubic foot, as calculated from the dew-point, or otherwise determined (art. 89), to that which would exist per cubic foot were the air saturated, or were the dew-point identical with the actual temperature. Thus a scale of degrees of humidity is formed, 1·00 being that of complete saturation, and 0 that of absolute dryness. In this sense of the word it will, of course, be readily understood that a low degree of "humidity" is compatible with the presence of a large quantity of aqueous vapour. It is not the vapour as such (which, while it exists as a gas, is, like all other gases, "dry"), but its readiness to be deposited in a "wet" state on a surface but little lower in temperature, that is intended to be expressed. To obviate the discordance between this language and that of common parlance, the terms "relative humidity" and "relative dryness" are sometimes used.

(200.) As a general meteorological fact, however, there is not merely a want of accordance, but an actual opposition between both the diurnal and annual progress of the "degree of humidity," or "relative humidity" of the air and the "tension of vapour," as indicated by hygrometric observation—a seeming paradox, but one very easily explained. To take the case in hand—the diurnal variation—we have seen that at those epochs of the night when the temperature has reached its lowest point, and dew is either actually deposited or nearly so, the humidity is at its maximum. But it is precisely at that moment that the supply of vapour from the earth having been for several hours cut off, or even a reverse process in progress, while yet vapour has been diffusing itself into the non-saturated regions aloft, and is still continuing to do so, the actual amount of moisture per cubic foot is small, and is still in process of diminution. This epoch is usually a little before sunrise. As the day advances, the temperature increases, and becomes more and more in excess of the dew-point. The air, therefore, becomes relatively drier, evaporation goes on more rapidly, the lower strata become fuller of vapour, as measured by its tension, which at length becomes such as to keep pace with the upward diffusion, which now in its turn is stimulated. The cloud-level, or vapour-plane, rises; and if the night has been clear, the air calm, the sun powerful, and the soil wet, the appearance of cumuli soon begins to render visible testimony to the nature of the process in progress. When the heat of the day has reached its maximum, this process is in its greatest activity. The "humidity" has now reached its minimum, and the evaporation, which is in the direct ratio of the temperature and relative dryness, its maximum. From this epoch, however, the supply of vapour from below being most copious, while the temperature no longer increases, it is evident that the humidity must begin to increase, while the tension also, for a longer or shorter time, will do the same, until by the decline of the sun the increase of humidity so far puts a stop to the evaporating process as to render it barely competent to supply the expense of upward diffusion, at which moment the tension becomes a maximum, and from which it also decreases, and continues to do so the humidity increasing, during the remainder of the twenty-four hours until next sunrise, when the same cycle of causes and effects will recur.

(201.) Such at least will be their succession in calm and clear weather, and in a normal state of circumstances; and as regards the generally contrary march of the relative humidity as compared with that of the temperature and the vapour-tension, such is really the course of the phenomena. The epochs, however, and their order of priority, are obviously very liable to be disturbed by a variety of circumstances, among which the most influential are rain, winds (especially such as recur in daily periodicity, as sea and land breezes), and cloud which cuts off the sunbeams from the soil, and puts a stop to the increase of evaporation *before* the temperature has attained its maximum, thereby tending to bring the epoch of maximum tension towards coincidence with that of maximum heat. We find, for example, on comparison of the three elements in question, as derived from six years two-hourly observations at the Royal Observatory at Greenwich (1842-1847), the following results:—

	Maximum.	Minimum.
Temperature,	55°·22 F. at 1h. 20m. P.M.	44°·85 F. at 4h. 10m. A.M.
Vapour-tension,	0·345 in. at 1h. 20m. P.M.	0·303 in. at 3h. 40m. A.M.
Humidity,	0·938 in. at 4h. 30m. A.M.	0·753 in. at 1h. 20m. P.M.

Where it should be observed that the amount of cloud at Greenwich is a maximum at 0 h. 20 m. P.M., at which hour 73 per cent of the sky, on a general average, is covered, and a minimum at 9 h. 44 m. P.M., when 60 per cent of cloud prevails, the general average of the year being two-thirds cloudy. For other exemplifications of the same law, the reader is referred to the table of normal results in fixed observatories at the end of this article.

(202.) The annual march of humidity and vapour-tension as compared with that of temperature depends on the same principles, and is governed by the same laws; the humidity, however (as is also the case with the diurnal cycle), being much more regular in its progress than the vapour-tension, and the limits between which the latter element oscillates being much wider, as might be expected from the greater duration of the cycle, and the consequently longer time given for the causes in action to work out their full effect before removal. Thus in Greenwich the annual maxima and minima, and their approximate epochs, as appears from the series of observations already referred to, are for the

	Annual Maximum.	Annual Minimum.
Temperature,	63°·37 F. in July.	34°·20 Jan.-Feb.
Vapour-tension,	0·466 in. in July.	0·195 in. Jan.
Humidity,	0·930 in. in Jan.	0·783 in. June.

(203.) *Of the general distribution of moisture through the atmosphere.*—Locally and temporarily, nothing can be more capricious than either the humidity or the vapour-tension, as we ascend into the higher regions of the air. Meteorologists, from Saussure and Deluc downwards, have sought in vain for anything like a regular law of decrement like that which at least approximately prevails respecting temperature. Mr Rush relates that in his sixteenth ascent to the height of 19440 feet in the Nassau balloon, June 29, 1850, with Mr Green, they traversed a stratum of air 8600 feet in thickness, in which *absolute hygrometric dryness*, the zero of vapour-tension, existed. This must of course be received with some reserve; but it suffices at least to show that in regions of the globe where cloud is the rule and pure sky the exception, masses of air are occasionally intermingled with the generally moist atmosphere, which would seem to have been all but absolutely drained of their moisture, either by long sojourn in the polar regions, or in the highest and coldest strata of the atmosphere. Meanwhile, at the ordinary levels, we know little at present of the average or *climatic* distribution of vapour. Of some things, however, we may be certain, viz., 1*st*, That on the open ocean, far from land, the dew-point, in the day time, can never be many degrees below the actual temperature of the air, and at night must always be very nearly identical with it. 2*dly*, That the mean vapour-tension in hot climates must necessarily be greater than in cold. 3*dly*, That, *cæteris paribus*, the relative humidity of the air must be a maximum over the sea, and a minimum in the interior of continents, especially where there is much sand, which allows the rain-water to sink, and which speedily dries at the surface; or much bare rock, which, never being more than superficially moistened, affords no supply of vapour to the air. For it is obvious that in such regions there must be less evaporation for an equal incidence of sunbeams; that therefore less of their heat will become latent, and their efficacy in heating the air will be in consequence greater, so that the temperature will rise in the day-time faster than the dew-point, and that in an increasing ratio; and, moreover, that from the very combination of these causes, there will be less tendency to the formation of cloud over such regions, and therefore a greater amount of direct sunshine thrown on the soil. Thus we have a system of mutually reacting causes and consequences (no uncommon arrangement in meteorology), all tending to exaggerate both the heat of the climate and its relative dryness: the only counteracting power being that of radiation, both diurnal and nocturnal, but especially the latter. Where, in addition to all these causes, those winds which blow from warmer regions or from tropical seas, before arriving over the place in question, have to pass over lofty mountain ranges, and have been chilled in so doing, and drained of their moisture, by the precipitation of snow or rain, it may well be imagined that a state of extreme relative aridity will prevail. 4*thly* and *lastly*, We may be very sure that the upper regions of the atmosphere (not only as being colder, and therefore incapable of retaining without deposition a quantity of vapour equal to that of the lower, but for the reasons assigned in art. 88) must be *habitually, and on a general average*, both absolutely and relatively drier than the lower, though the existence of cirrus cloud at very high levels (certainly sometimes exceeding 30000 feet) sufficiently proves that even at such altitudes saturation with moisture occasionally takes place. During the sojourn of Mr P. Smyth on the Peak of Teneriffe, the aridity of the air was found to be always excessive. On one occasion at Guajara (alt. 8843 feet) the depression of the dew-point below the temperature of the air was observed to be no less than 54° F., and on another, at Alta Vista (10707 feet), 40°, the depression at the sea level being habitually about 10° in the middle of the day.

(204.) In actual cloud (although in the earlier history of hygrometry the fact was questioned, owing to the imperfection of the hygrometers used), both common sense and observation go to prove that the extreme point of humidity is attained, since where water is bodily present in every cubic inch of air, and refuses to disappear by evaporation, a state of absolute saturation must exist, just as in brine in which finely powdered salt is suspended without solution we conclude a state of saline saturation. Hence we are led to some singular enough conclusions with respect to the law of decrement of *humidity*, as distinct from vapour-tension.

(205.) In the day time, so long as the sky is cloudless over any spot, it is evident that there is no point in the aerial column above it at which the dew point is surpassed, so that the supply of moisture from below is carried off by diffusion upwards, and it will depend entirely on the copiousness of this supply, and the rapidity with which it ascends into the higher regions, whether, as the day advances, the vapour-tension and humidity shall follow a contrary or similar progression. If the supply be abundant and borne up rapidly to a colder level, a cloud will be formed, and it is obvious that for some time before its actual visible appearance, the air in that region where it is about to be formed must be gradually approaching saturation, and attain it at the moment of deposition of the first molecule of water in a liquid state (and here we cannot help remarking, *obiter*, that it is utterly inconceivable how, under such circumstances, a *vesicle* should be formed). From the ground, then, up to the vapour-plane, wherever such plane exists, whatever be the law of vapour-tension, the humidity (perhaps with some interruptions in respect of regularity) continually increases up to 1·000, its natural limit, which it maintains through the whole thickness of the cloud stratum. This level passed, the upper surface of the cloud *performs, to all intents and purposes, as regards the higher atmosphere, the office of a lake or sea*, being a thoroughly *wet* surface on which that atmosphere reposes. Henceforward, therefore, the law of decrement of moisture will be the same as it would be over the sea itself under the same circumstances of temperature and pressure. Nor does anything prevent (the sun striking on and evaporating it) why a second layer of cloud should not be formed again at a higher level, and so on—a phenomenon, in fact, of no rare occurrence. In such a case, if we take the height for an abscissa, as A B, the curve of humidity will be an undulating one, such as E F G H I, attaining its maximum, 1·000 (= B F or C H) at F or H, and having a minimum between them as at G, while the curve of tension P Q R S T follows a progression totally different—the relation between any pair of their respective ordinates, C H, C S, being that which subsists between the

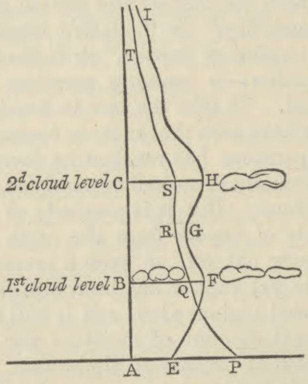

Fig. 8.

temperature, tension, and humidity generally, a relation expressible by the equation,

$$V = H \,.\, \varphi(t)$$

where V is the vapour-tension, H the humidity, and $\varphi(t)$ the function of the temperature t, which expresses the force of saturated vapour at that temperature (art. 92).

(206.) *Dependency of atmospheric pressure, temperature, and moisture on the direction of the wind. Dove's general views of this dependence.*

There can be no doubt that by persevering and long-continued observation, the same laws of diurnal and annual periodicity will be found to be observed in the direction and force of the wind as in the other meteorological elements; but they are so much more masked by what we must at present term casual and accidental causes, that, except in certain great features (such as have already been described, art. 58, *et seq.*) and in certain geographical situations, they cannot emerge from the mass of overlying irregularities except in very long periods. The extreme mobility of the air, the powerful agencies at work to set it in motion, and the extensive propagation and prolonged duration of movements once communicated to an elastic fluid so constituted, all go to mix up, at each particular spot and moment, into one common resultant, motions which have originated at many very remote points, and at very different epochs. Along the coasts of heated continents, or even islands in tropical regions, indeed, the diurnal alternation of sea and land breezes is a result obvious enough of itself and confirmed by observation; and in the temperate zones, the approach of the sun to their respective poles is masked by a bias in the general direction of the wind towards an easterly, and its recess by one towards a westerly direction, the more marked the nearer the point of observation is to the exterior limit of the trade winds. But as regards the wind in general, it is found more advantageous to abandon this point of view, and to regard it, not in its remote connection with the general cause of periodicity, but in its immediate relation to the other meteorological elements with which it stands in more obvious connection.

(207.) The winds, which are originally caused by the equatorial heat and generation of aqueous vapour, or by extensive local agencies of the same kind elsewhere produced, act as their transporters from place to place, and as their distributors over the globe. It is, therefore, very obvious that a wind blowing with any degree of continuance and force from a lower to a higher latitude must bring with it to the latter both the superior temperature and moisture of the region it has left, and *vice versâ.* Thus in our latitude, a south-west wind is warm and moist, a north-east cold and dry. The excess of vapour in the former has a powerful tendency to form cloud in coming into a colder climate, and to be deposited in rain; the latter arriving with a low vapour-tension in a warmer region, absorbs both heat and moisture, clearing the sky of cloud, and, while depressing the temperature, gives that peculiar "bracing" quality which is the effect of a cold, dry air, in contrast with the "relaxing" influence of moist warmth. These effects are familiar to every one, and have been remarked from the earliest times. The general indication thus afforded has been, however, pursued into minute detail by M. Dove in his excellent work entitled *Meteorologische Untersuchungen* (Berlin, 1832), in which he has succeeded in exhibiting in a very distinct manner, by an extensive induction from observations in almost every region of the globe, the close and immediate dependence of all the three great meteorological elements, temperature, moisture, and atmospheric pressure, on the direction of the wind, or the point of the compass from which it blows. In other words, assuming θ to represent the angle which that direction makes with the meridian of the place (reckoned from the north or south according to the denomination of the elevated pole), any one of these elements, E, is found to be expressible, on an average or mean value during a whole year or series of years, by the equation of the form,

$$E = A + B_1 \,.\, \sin.\,(\theta + C_1) + B_2 \,.\, \sin.\,(2\,\theta + C_2) + \&c. \ldots (a)$$

(208.) The mode in which a law of this kind may originate is not difficult to understand. Suppose, 1*st*, the earth without diurnal rotation, and the sun to move round it from east to west, and at any given spot (suppose in the northern hemisphere) let a wind blow direct from the south with a certain force and during a certain time, this will bring over the place of observation the warmth and moisture of a latitude more southerly (suppose) by 10°. But now suppose a wind of the same force to blow for the same time, not from the south, but from the eastward or westward of south, at an angle $\theta°$ with the meridian: the atmosphere of a place 10° remote, measured on a great circle, will be still transferred to the place, but owing to the inclination of its path, only $10° \times \cos.\,\theta$ more south. If, therefore, the former wind brought with it an accession of temperature or moisture, represented by e, this will bring the accession $e \,.\, \cos.\,\theta$ proportional to the difference of latitude travelled over. It may happen, however, from the circumstances of the locality, that the warmest or moistest region in the neighbourhood may lie, not due south of the place, but in a direction making an angle $90° - C$ with the meridian. In this case, then, the extraneous temperature, or moisture so induced, will obviously be represented, not simply by $e \,.\, \cos.\,\theta$, but by $e \,.\, \cos.\,(\theta + C - 90°)$ or $e \,.\, \sin.\,(\theta + C)$.

(209.) The effect of the earth's diurnal rotation is to cause a wind setting in from the southward to veer more and more westerly the longer it has continued to blow, and from the northward more easterly, so that, to use M. Dove's expression, the direction of the wind belies the region from which it has travelled. The wind, therefore, which really reaches the spot in question from the most southern region (and which brings the greatest amount of extraneous heat and moisture) will not be a south wind on its arrival, but one having more or less of a westerly character, according to the latitude of the place and other circumstances of local resistance, and *vice versâ* for the opposite influences. In so far, then, as the great equatorial and polar system of wind-currents is concerned, the general effect will be represented nearly by the formula,

$$e \,.\, \sin.\,(\theta + C')$$

on a mean of every season and of every direction of the wind; and if to this be added the subordinate influences which may be propagated to the locality in question from regions nearer at hand than the equator, and which may each and all of them give rise to similar effects, represented by $e' .\, \sin.\,(\theta + c')$, $e'' .\, \sin.\,(\theta + c'')$, the total effect, being the sum of all these, will, as is easily seen, be reducible to a single term of the general form, $E \,.\, \sin.\,(\theta + C)$.

(210.) The effect of any wind in heating a place will evidently be proportional not merely to its excess of temperature, but to the quantity of air having that excess which passes over the place, and which has changed its latitude, that is to say, in the absence of any information as to its velocity, to the degree of frequency and duration of that particular wind. The co-efficient

e, then, in the expression $e \,.\, \sin.\,(\theta + C)$ is dependent on this degree, which itself, in any given locality, is dependent on θ, the north-east and south-west winds being most frequent, and the other winds rarer, in some definite relation to their duration. In other words, e is a function of θ, having two maxima, viz., for $\theta = 45°$ and 225°, and two intermediate minima, not necessarily at right angles to these. e, then, may be conceived as generally capable of expression in some such form as $(e) + f \,.\, \sin.\,(\theta + g) + h \,.\, \sin.\,(2\,\theta + i)$, the combination of which with $\sin.\,(\theta + 45°)$, or $\sin.\,(\theta + C)$, will give rise to a set of terms containing the sines and cosines of θ and its multiples, with co-efficients depending on $(e), f, g$, &c., and which are reducible, in their ultimate expression, to the general form in art. 146.

(211.) The dependence of the barometric pressure on θ in a similar form of expression is not so evident on these principles. But it must be remembered that a warm and moist atmosphere is lighter, bulk for bulk, than a dry and cold one, and that as the effect of a surface wind (at least of one of any continuance) is to transfer bodily the lower strata of the atmosphere of one place to another, so the barometer, apart from all other causes of periodical fluctuation, will vary in inverse correspondence with the temperature and moisture.

(212.) M. Dove, and after him Kämtz and others, following out in greater detail this train of inquiry, have come to very positive and distinct practical conclusions on all these several heads. In fact, it appears, as a general law, that in the "wind-rose," or compass-card, there are two points not far from diametrically opposite each other: the one in the neighbourhood of the NE. point, the other in that of the SW., from which when the wind blows, *on the long average*, both the temperature and the vapour-tension have their maxima and minima, the former at the NE., and the latter at the SW. The same, or nearly the same, points or poles of the compass-card indicate, reversely, the minimum and maximum of barometric pressure. Particular localities show deviations from each other and from the general and normal form of expression, both in respect of the precise situation of these "weather-poles" on the compass-card, and in their exact diametral opposition, as also in the situation of the intermediate mean position. On the whole, however, for each locality, and for each of the three elements in question, it is found practicable to represent its variation, in terms of the azimuth θ of the direction of the wind, by the expression,

$$E = A + B_1 \,.\, \sin.\,(\theta + C_1) + B_2 \,.\, \sin.\,(2\,\theta + C_2)$$

in which C_1 is very nearly the same angle for all of them, and in which B_2, the co-efficient of the term of the second order, is found to be small in comparison of B_1, that of the first. And it is evident that the total barometric pressure $P + p$, and the vapour-pressure p, having both this form of expression, their difference P, or the pressure of dry air, will admit of a similar one by a proper determination of its co-efficients, which are easily deduced from those of its component elements by putting

$$\begin{aligned} &P_0 + P_1 \,.\, \sin.\,(\theta + C_1) + P_2 \,.\, \sin.\,(2\,\theta + C_2) \\ &+ p_0 + p_1 \,.\, \sin.\,(\theta + c_1) + p_2 \,.\, \sin.\,(2\,\theta + c_2) \\ &= P'_0 + P'_1 \,.\, \sin.\,(\theta + C'_1) + P'_2 \,.\, \sin.\,(2\theta + C'_2) \end{aligned}$$

where P' represents the mixed pressure, and the several numbered and accented letters the respective co-efficients of the general formula, and which, reduced by the usual trigonometrical transformations, afford equations by which any one set of these values may easily be derived from the other two. It is evident, moreover, without any calculation of this kind (as M. Dove observes), that since the elastic power of the vapour has its maximum at the SW. point, where the *total* barometric pressure has its minimum, the dry pressure P must have its minimum there also; in other words, that c_1 being approximately $= C_1 + 180°$, C'_1 will be nearly identical with C.

(213.) Pursuing the inquiry still further, M. Dove finds, as indeed might be expected, that these co-efficients are severally and separately, like all meteorological local elements, periodical functions of the season of the year, or of the sun's mean longitude; and he has been enabled to assign for several localities their spring, summer, autumn, and winter values, his conclusions having been completely established, in their general expression, by all subsequent observation.

(214.) It is sufficiently obvious, from the principle with which we set out (art. 208), that a similar series of relations ought also to subsist in the southern hemisphere, *mutatis mutandis*; that is to say, that the directions of the maxima and minima, instead of NE. and SW., will be SE. and NW., in conformity with the general law of the winds in the two hemispheres.

(215.) As an example of the results obtained in this branch of meteorological enquiry, we shall here set down the values of the co-efficients in the expression $E = A + B_1 \,.\, \sin.\,(\theta + C_1) + \&c. \;.\;.\;.\;.$ as calculated by Prof. Johnson from the series of meteorological observations made under his superintendence at the Radcliffe Observatory at Oxford. These are (*Radcl. Obs.* 1854, p. xxvi.) for the

	A	B_1	C_1	B_2
Temperature T	48°·60 F.	2°·34	254°35′	0
Dry Pressure P	29·404 inch.	0·108 inch.	75 33	0
Vapour-Press. p	0·307 inch.	0·026 inch.	259 39	0

where it will be noticed, that 180°+75°33′=251° 33′, and therefore, conformably to the theoretical views above delivered, the dry pressure has its minimum very nearly corresponding to the maximum of temperature and of vapour-pressure. Whenever, as in this case, which is the most common, the terms of the second and higher orders, are insensible or nearly so, the co-efficient B_1 determines the maxima and minima, so that the respective values of $2\,B_1$ will express the total amount of fluctuation in temperature, pressure, &c., at the stations which have their origin in changes of wind.

(216.) It is very easy to perceive that with this dependence of the great elements of weather upon the direction of the wind, the other features which stand to them in the relation either of immediate consequences or proximate causes, must go hand in hand—such as cloud, rain, &c. For instance, at Karlsbad, from the calculations of Eisenlohr, it appears that, during the prevalence of SW. wind, 1 day out of 17·29 on an average only is free from cloud, and during that of NE. 1 out of 3·04, the intermediate winds being accompanied with intermediate degrees of frequency. So also for rain: 1 day out of 2·75 during SW., and one out of 11·92 NE.; the minimum of rain, however, here occurring with an E. or ENE. wind; stormy weather 1 out of 17·36 of SW., and 401·50 NE., clearly indicating the influence of the headlong down-rush of the upper equatorial current of the *anti-trades* in the manner indicated (art. 62.)

(217.) Not less distinctly marked is the degree of frequency of each particular direction of wind in connection with the direction itself. Out of 40 places enumerated by Dove in every part of Europe in which sufficiently prolonged series of observations of the direction of the wind had been collected by him, 21 have a very large and decided predominance of days of west wind, 16 of SW., 2 only of NW., and only one (Kasan) SE. We have already seen (art. 83) that the prevalent wind in Europe generally is WSW. or thereabouts. After these, the other or inferior maximum occurs at E. in 18 places, NE. in 11, N. in 5, and SE. in 6, the average direction of this maximum being about ENE. so that the position advanced in art. 216 is fully borne out by observation.

(218.) At the end of this essay the reader will find a table containing the mean, the maximum, and the minimum values (with their epochs diurnal and annual) of the principal meteorological elements obtained from the data afforded by the best and most systematically conducted series of observations, being for the most part those which have been carried on since 1840, in the magnetic and meteorological observations established by the British, Russian, American, Belgian, and other governments, and national and local institutions, on a concerted system of hourly or bi-hourly observation. They afford numerous and striking exemplifications of the laws explained above, and clearly show their general applicability, especially as regards the contrary march, both annual and diurnal, of the humidity and vapour-tension; the greater range of the annual as compared with the diurnal fluctuations, and the dependence of the average amount of vapour present in the air, and the extent of both kinds of fluctuation on the latitude. It would have been easy to have covered our pages, indeed to fill volumes with climatological records and statements, such as the reader will find in Humboldt (*Asie Centrale*, vol. iii.), amassed by the diligence of Mahlman; in the more extensive collections of the latter and Prof. Dove, in the 4th vol. of the *Repertorium der Physik;* and in the Reports of the Senate of the University of New York to Congress; the *Correspondence Meteorologique* of the Russian observatories, &c. Not only, however, do the limits allowed us forbid the adoption of such a course, but we consider it more instructive to concentrate attention upon a few carefully determined and selected cases than to diffuse it over a larger field of bewildering particulars.

Optical Phenomena of Meteorology—1. *The Rainbow.*

(219.) The explanation of the rainbow, suggested by Roger Bacon, but only first clearly made out by Newton, is so familiar an illustration of the laws of coloured refraction in every treatise on optics, that we should not have thought of introducing it into this essay but for the vagueness of idea and misconception which are generally prevalent respecting the origin of the "supernumerary bows," *i.e.*, those coloured fringes which are often seen in the interior of the primary rainbow, and more rarely (on account of the comparative faintness of the whole phenomenon) at the exterior of the secondary rainbow. They have been explained by Dr Young on his fertile principle of interferences, but his explanation (*Phil. Trans.* 1804) is so obscurely expressed, or rather indicated, as to be hardly intelligible, which is perhaps the reason why Kämtz, the most exact and industrious of reporters in matters of meteorological theory, while assembling all the other explanations which from time to time had been put forth by Pemberton, Venturi, Brandes, and others (some of them very absurd, and with none of which he appears to feel satisfied), passes this, the only correct one, in silence. Neither is it noticed by M. Pouillet in his recent elaborate *Elémens de Physique*, who in place of it, offers a surmise as to their origin which cannot be the true one, and which is refuted by an experiment of M. Babinet, which he cites in illustration. Mr Coddington, in his treatise on reflexion and refraction, explains only the Newtonian Bows, his subject not extending to the phenomena of interferences, while Dr Lloyd, in his treatise on light and vision, contents himself with mentioning the fact of their having been explained by Dr Young, without giving the steps of the explanation. We shall not, therefore, scruple to devote some small portion of our allotted space to rescuing this very beautiful illustration of the law of interference from unmerited neglect.

(220). Let θ be the angle of incidence of a solar ray on the surface of a spherical drop of water (θ being 0° when the ray enters at the vertex next the sun, and passes diametrically through the drop, and 90° where it just grazes its circumference), φ the corresponding angle of refraction, and μ the refractive index for a ray of any given colour, μ being greatest for violet and least for red rays. Then shall we have $\sin. \theta = \mu . \sin. \varphi$, and the deviation of the ray by refraction will be $\theta - \varphi$. If the ray be reflected internally after entering the drop, it is easy to see, by tracing its course within the sphere, that at each reflexion an additional deviation in the same direction of $180° - 2\varphi$ will take place, and at its final emergence a further deviation (still in the same direction) equal to that at entering or $= \theta - \varphi$, so that the total deviation after n reflections will amount to $n . 180° + 2\theta - 2(n+1)\varphi$, which is a function of θ in virtue of the relation $\sin. \theta = \mu . \sin. \varphi$; ($a$) Now this function, which is $n . 180°$ when $\theta = 0$, diminishes as θ increases (since μ being nearly $\frac{3}{2}$, $2(n+1)\mu$ is necessarily greater than 2), and continues to diminish until it attains a minimum, when its differential vanishes, or when $d\theta = (n+1)\, d\varphi$, which, by eliminating $d\varphi$ by combining this with the differential of equation (a), gives

$$\sin. \theta = \sqrt{\frac{(n+1)^2 - \mu^2}{(n+1)^2 - 1}}$$

and for the case of the primary bow, where $n = 1$, $\sin. \theta = \sqrt{\frac{4 - \mu^2}{3}}$ in which substituting for μ the exact refractive indices of the extreme red and violet rays for water, we find for the red rays $\theta = 59° 32'$, $\varphi = 40° 22'$, and Δ (the deviation) $= 137° 36'$, and for the violet the corresponding values 58° 46′, 39° 30′, 139° 32′. When the deviation is a minimum, the rays incident more and more remotely from the vertex of the drop, and which, up to that point, were dispersed at their emergence by their change of deviation, cease to be so, and emerge parallel. An eye, then, properly situated with respect to the drop will receive a parallel red pencil of rays in a direction 137° 36′ remote from that of the sun, and one of violet in a direction 139° 32′ remote from it; or, in other words, at the angular distances 42° 24′ and 40° 28′ respectively, from the point of the heavens opposite to the sun, which are therefore the angular radii of the elementary red and violet rainbows.

(221.) So far the Newtonian explanation of the bow. As regards the fringes, if we put $D = 180° - \Delta$, it is evident that D will represent the deviation of the emergent ray, not from the direction in which the sun's rays *proceed*, but from that in which the sun is *seen*, and will therefore express the *dispersion outwards* of the emergent ray from the latter direction, and will be a maximum when Δ is a minimum. The parallel *pencil of rays*, therefore, by which the rainbow is seen, has the maximum angle of dispersion outwards from the sun, and all other rays at their emergence will have a less, whether their points of emergence be nearer to or farther from the vertex of the drop. For every such point, then, *more* remote from the vertex, it will be possible to find a corresponding point less remote, such that individual rays (*not pencils*) emerging from both shall have the same angle of dispersion; and which, of course, shall pursue parallel directions, and when incident on the eye shall be collected on the same precise point of the retina, and shall therefore be in a condition to interfere with, and destroy or reinforce each other, according to the difference of their total paths traversed both within and without the drop, before reaching the eye.

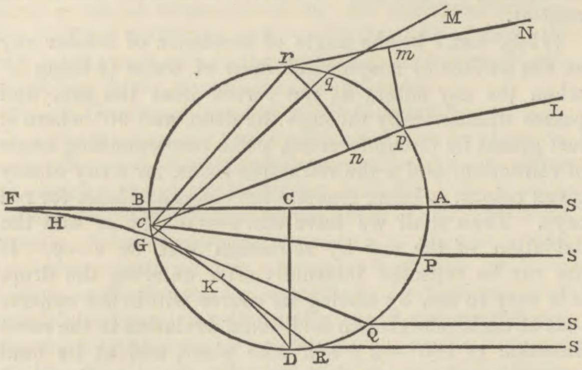

Fig. 9.

(222.) Let A B D be a section of the drop through the sun (in the direction C S from the centre C). Draw D E perpendicular to C S; and taking the principal focus for rays refracted at the convex surface E A D, let D G F be the caustic of the quadrant D A. Let S Q G *q*, be the course of the pencil of rays which emerges parallel along *q* M (as the drop's contribution to the rainbow), and taking any point P between A and Q, draw P *c* H, touching the caustic in H, and cutting the surface in *c*. Then will P *c* be the course of the refracted ray before, and *cp* after reflexion, and *p* L its ultimate diversion on emergence. From *c* draw *c* K R touching the caustic in R. This will be the direction of another ray S R after refraction, and supposing *c r* to be its reflected course, the incidences of the rays *cp*, *c r*, on the one side of the sphere will be symmetrical to those of *c* P, *c* R, on the other, and therefore P S and R S (regarded as rays from *c* refracted outwards) being parallel to each other, *r* N and *p* L, the courses of *c r* and *c p* after emergence, will also be so; and P, R will lie on opposite sides of Q, and *p*, *r* of *q*, because as *c* approaches to G the point where the caustic meets the sphere, H and K both do so also. P and R approach and ultimately coincide at Q, and *p r* at *q*, the latter being the point at which *contiguous* rays emerge parallel. Thus, for every point of emergence *p* nearer the vertex than *q*, another *r* more remote has been found, under the condition appropriate to the interference of the emergent rays.

(223.) Thus we see that every ray emerging between A and *q* will have a fellow ray emerging parallel to it between *q* and E, and interfering with it by a difference of undulations, determined by drawing *p m* perpendicular to *r* N, and *r n* a circle, having *c* for its centre; for the difference in question (δ) will be expressed by $\frac{r\,m}{v} - \frac{n\,p}{v'}$ where v, v' are the velocities of light in air and in water, that is, since $v' : v :: 1 : \mu$, by $r\,m - \mu \,.\, n\,p$. It is not necessary to go into any calculation of the value of this; it is sufficient that it increases regularly from 0 (when *r* and *p* coincide with *q*) *not merely because both r m and n p vanish there*, but because at *q* and its neighbourhood $r\,m : n\,p :: \mu : 1$, so that the parallel rays which form the rainbow have no difference of phase, while as the inclination of the emergent rays *r* N, *p l*, to the visual ray of the rainbow *q* M increases, so does also their difference of phases.

(224.) The larger the drop the greater are the linear magnitudes of all the elements composing its form, and therefore of *r m* and *n p*, and consequently δ. Hence, to the same difference of angular directions between the rainbow and any pair of interfering rays will correspond a larger value of δ the larger the drop, and therefore a greater difference of phase and number of fringes; or, in other words, the angular breadths of the successive fringes are inversely as the diameters of the drops. If, then, the drops differ much in diameter, and there be no greatly prevalent average diameter, the fringes formed by one drop will confuse those by another. It is only, then, when owing to some existing condition in the formation of the rain, there is a large preponderance of drops having very nearly the same diameter that these fringes will be visible. They are especially well seen, and the whole phenomenon of the primary bow is exhibited with peculiar distinctness, when on a sunny morning the eye is held close to a gossamer covered with dew (in perfectly distinct microscopic globules of nearly equal magnitude), the back being turned to the sun and the head so placed as to allow his light to fall laterally on the net-work on which the globules are strung like beads. Four or five internal fringes may be distinctly traced within the bow formed by an even undisturbed gossamer.

(225.) The angle of dispersion D being a maximum for rays forming the rainbow, it is obvious that no drop outside of the bow can send to the eye any ray once internally reflected from the sun. Hence the greater apparent illumination of the ground of the sky inside of the bow. The rainbow ray is, in fact, the asymptote of the exterior caustic for rays twice refracted and once reflected.

(226.) In reference to the formation of a rainbow on cloud or fog in the entire absence of rain (art. 93), Colonel Sykes, in his paper on the Meteorology of the Deccan (*Phil. Trans.* 1835), relates a remarkable instance of one seen by him from the top of a precipice from 2000 to 3000 feet in perpendicular height, forming the north-west scarp of the hill fort of Hurrachandarghur, among the Ghauts, overlooking the plains of the Concan (Konkhun), densely covered with fog-cloud, rising somewhat above the level of the precipice, but not covering it. Under these circumstances, having the sun at a low elevation at his back, he says, "A circular rainbow appeared, quite perfect, of the most vivid colours, one half above the level on which I stood, the other below it. Shadows in distinct outline of myself, my horse, and people, appeared in the centre of the circle, as in a picture to which the bow formed a resplendent frame." "From our proximity to the fog, I believe the diameter of the circle at no time exceeded 50 or 60 feet. The brilliant circle was accompanied with the usual outer bow in fainter colours." In the same paper, he also records his observation of a white rainbow in a fog-bank near Poonah, within which he was riding. "Suddenly I found myself emerge from the fog, which terminated abruptly in a wall some hundred feet high. Shortly after sunrise, I turned my horse's head homewards, and was surprised to discover in the mural termination of the fog-bank a perfect rainbow, defined in its outline, but destitute of prismatic colours." "Niehbuhr, in his Voyage to Africa, describes a white rainbow, and Mr St John, in his Lives of Celebrated Travellers (iii. 121), mentions having seen one, on the 21st May 1830, in Normandy, on 'the morning mist.'" On the other hand, it should be mentioned that Mr Smyth, in his recent sojourn on the Peak of Teneriffe, with a cloudless sky and perpetual sunshine above, and with a boundless sea of cloud continually extended in all directions below him, makes no mention of a rainbow being at any time formed upon it.

(227.) *Halos.*—These are of two kinds: the first, large circles of definite and constant diameters, one of 45°, the other of 92°, and which are seldom both seen together. The colours are very feeble, especially of the larger, which is usually almost or quite white. The formation of the lesser of these, as explained by Mariotte, is due to the existence of minute prisms of ice floating in the air, having refracting angles of 60°, and their axes turned in all possible directions. If we take a triangular prism of glass, and turn it about in a sunbeam, it will refract out from one of its angles a coloured beam, whose deviation from the direction of the incident light varies as the prism is turned, being at first very great, but diminishing until at one point of the rotation the deviated beam becomes for a while stationary, and then (the rotation continuing in the same direction) begins again to increase. There exists, then, for every refracting angle of the prism a minimum angle of deviation, dependent on the refractive density and the angle of the prism. In ice, with a refracting angle of 60°, this deviation is about 23° for red light, and therefore, among an infinite multitude of such prisms scattered through the air, a far greater number will throw out a refracted beam 23° inclined to the direct ray of the luminary than in any other direction, since about the position of the maximum a considerable amount of rotation of the prism causes but a very trifling change in the direction of the refracted ray. At the angular distance of 23°, then, from the apparent place of the luminary, there will be a much larger percentage of prisms in the visual line capable of sending a refracted beam to the eye than at any other, and a dim circle faintly coloured with red internally, and better defined within than without, will be seen.

(228.) The halo of 92° diameter is accounted for in a similar manner by refraction through the angle of 90°, at which the sides of hexagonal or triangular prisms intersect their basis, and which in ice gives a minimum deviation for red rays of about 46°. Besides the agreement of these angles assigned by theory with the measured semidiameters of the halos, we have a direct proof, in the fact observed by Arago, that their light is partially polarized in a plane tangent to the circumference of their circles, that they consist of refracted light. The light of the rainbow, similarly examined, indicates reflexion as its principal origin, being polarized in a plane at right angles to the arc, or passing through the sun.

(229.) Besides these principal halos there are smaller ones which are frequently seen encircling the moon, often two, very rarely three, and which are sometimes called *coronas*, a very proper distinction, their origin being quite different from that of the large ones as well as their colours, which are much more lively and inverse as to their order, the red being outward and the violet inward. When two or more are seen at once, the diameter of the second is double that of the first—of the third triple. But the diameter of the interior corona (the unit of the scale) is not always the same, varying from 2° to 4°. The succession of colours is approximately that of the reflected series of thin plates, and they are obviously interference fringes, and as such have been very satisfactorily explained by Dr Young, who considers them to arise from the interference of rays passing on either side of minute globules, all (or a preponderant average) of which have at the time very nearly the same size, assimilating them to the colours of fine even-stapled wool or to lycoperdon dusted over glass, and held between a candle and the eye. Dewed glass so held often exhibits similar rings, and occasionally the cornea of the eye itself becomes filmy by the diffusion over it of minute particles which (such at least is our personal experience) exhibit round a candle two or three beautiful coronas, the second of 17° 57′ in diameter, of vivid colours and most perfect definition. The reason why coronas are seldom seen round the sun is the dazzling brightness of that luminary. If its light be enfeebled by reflection in water, or by a coloured glass, they are often visible. Newton observed three such on one occasion by this means.

(230.) Interference colours are frequently seen irregularly distributed over cloud masses. We had the satisfaction of witnessing a fine display of them from the Col du Mont Cervin on the occasion of an ascent of the Breithorn (Kleine Monte Rosa) in 1821, and since, in cirro-stratus covering the sun, on Sept. 17, 1852, when the pink, blue, and green colours of a mackarel's skin were visible in irregular patches. But the beautiful phenomenon, which it was our good fortune to observe on the 14th July 1841, at 4h. 50m. P.M., being, so far as our reading extends, unique in meteorology, appears to merit a particular description. While riding on that occasion near Hawkhurst, in Kent, with a companion, the attention of both was attracted by the pale well-defined silvery disc of the sun as seen through a very high cloud, of a character between cirro-stratus and cirro-cumulus—like a high "mackarel sky" blotted by a remarkably uniform fog. After a few moments we perceived the edges of the cloud to be beautifully tinged with bands of colour, not disposed in a circular form round the sun as a centre, but following all the sinuosities of the outline of the cloud. The colours, commencing from the white area forming its interior and proceeding outward to the edge, were—1*st*, white; 2*d*, very pale pink; 3*d*, blue-green, a stronger colour; 4*th* (at the edge), purplish pink, considerably intense; beyond which pure blue sky. At one place a 5th band of colour, blue-green (very different from the blue of the sky) formed the edge; the line of demarcation between this and No. 4 distinctly running out at the edge so as to *cut* the outline of the cloud. What, however was especially remarkable, was that *the same fringes were observed bordering detached portions of neighbouring clouds of similar character*, the colours having obviously no reference to more or less proximity to the sun, but *depending on the thickness of the cloud* or the length of the path within it traversed by the visible ray. After watching this phenomenon for a quarter of an hour, the coloured bands grew broader and the tints very strong, and a tendency to form a corona about the sun was perceived. Probably with a darkening glass, one or more might have been well made out. It seems impossible to regard these colours otherwise than as the resultants of the super-position of a series of interference fringes following a regular progression of breadth (due to a progressively increasing size of the drops) from the exterior to the interior of the cloud.

(231.) *Parhelia and bands of light passing through the sun.*—A horizontal band of light is occasionally seen to pass through the sun when at a low altitude, and to be prolonged into a circle parallel to the horizon. This is evidently what would result from reflection on, or refraction through, the faces of innumerable ice prisms floating in *perfectly calm* air with their axes vertical, but having their lateral faces disposed equally in all azimuths. Minute crystals, when formed by precipitation in a liquid at rest, always arrange themselves with their axes parallel as they sink, which may often be rendered sensible by a silky appearance in the liquid produced by agitation (of which iodide of lead precipitated from a dilute solution containing ether affords a beautiful example). Under this condition, then, the dispersed light, which in the halos is scattered in all planes equally, is here confined to a horizontal one, resulting in a bright horizontal circle, the parhelia being the intensified effects of a greater condensation of the dispersed rays at the angles of minimum dispersion, corresponding to the halo itself as the circle does to the diffused illumination of the cloud on which the halo is depicted.

(232.) Any one who considers the complicated forms of snow crystals (art. 120), and the various ways in which refractions and reflections, both external and internal, may take place among them, bearing in mind also that ice is *doubly refractive*, and that at the planes of junction of macled crystals, phenomena of coloration of an intricate nature are presented, will not be surprised to find a great variety and complication of luminous arcs, more or less coloured, and intersecting one another in such a way as to form singular interlaced patterns, occasionally developed under the influence of a bright sun, intense frost, and generally clear sky, on the principles above explained; such, for instance, as the superb exhibition witnessed by Scheiner at Rome in 1629, and repeated in higher perfection, and with fuller detail, for several days in succession, at Moscow, when occupied by the French army in 1812. This most striking phenomenon, which is very seldom more than partially visible, consists of two brilliant halos about the sun, cut diametrically across by a horizontal circle continued all round the heavens, with well-developed parhelia at their intersections, and a third at a very large angular distance, more feeble, the intersections also marked with parhelia. At the summits of the two inner halos, and touching them externally, other circles, as it were their reflected images, pass upwards and include the zenith, that which touches the inner halo having a parhelion at the point of contact. Circles of this description are clearly not phenomena of interference, and can only admit of explanation by the intervention of ice crystals.

(233.) *Polarization of Sky Light.*—This is a very mysterious and a very beautiful phenomenon, when explored by the aid of a polariscope, consisting of a tourmaline plate, with a slice of Iceland crystal or nitre, cut at right angles to its optic axis, and applied on the side of the tourmaline farthest from the eye. In a cloudless day, if the sky be explored in all parts by looking through this compound plate, the polarized rings will be seen developed with more or less intensity in every region but that nearest the sun and that most distant from it—the maximum of polarization taking place on a zone of the sky 90° from the sun, or in a great circle having the sun for one of its poles. The plane of polarization, whatever the direction of the visual ray, passes through the sun, so that the cause of polarization is evidently a reflexion of the sun's light *on something*. The question is, on what? Were the angle of maximum polarization 76°, we should look to water or ice for the reflecting body, however inconceivable the existence in a cloudless atmosphere and a hot summer day of unevaporated molecules of water. But though we were once of this opinion (art. LIGHT, *Encycl. Metropol.* § 1143), careful observation has satisfied us that 90°, or thereabouts, is the correct angle, and that therefore, whatever be the body on which the light has been reflected, *if polarized by a single reflexion*, the "polarizing angle" must be 45°, and the index of refraction, which is the tangent of that angle, unity; in other words, the reflection would require to be made *in* air *upon* air! The only imaginable way in which this could happen would be at the plane of contact of two portions of air differently heated, such as *might* be supposed to occur at almost every point of the atmosphere in a bright sunny day; but against this there seems to be an insuperable objection. The polarization is most regular and complete, as we have lately been able to satisfy ourselves under the most favourable possible atmospheric conditions, after sunset, in the bright twilight of a summer night, with the sun some degrees below the horizon, and long after all the tremors and turmoil of the air, due to irregular heating, must have completely subsided. Even at midnight, the moonlit sky[1] exhibits the same phenomenon, bearing the same reference to the moon's position as to that of the sun by day, the black cross of the polariscope being distinctly perceptible. The difficulty, therefore, of conceiving the polarization as operated by a single reflexion is very great. On the other hand, if effected by several successive reflexions, what is to secure a large majority of them being in one plane (in which case only their polarizing effect would accumulate); and of those which become ultimately effective, what is there to determine an ultimate deviation of 90° as that of the maximum? The more the subject is considered, the more it will be found beset with difficulties; and its explanation, when arrived at, will probably be found to carry with it that of the blue colour of the sky itself, and of the great quantity of light which (whether reflected, refracted, or fluorescent) it actually does send down to us, and of which we confess our inability to render any account less unsatisfactory than that of Newton, who refers it to reflexion on thin transparent particles. These cannot be air, because there can be no reflexion upon air in contact with air of the same density. And they cannot be water, it being impossible to realize even in imagination the existence of globules or bubbles of the requisite dimensions maintaining themselves unevaporated for an instant, when disseminated through the atmosphere of a clear, dry, and sultry day, when through its whole extent there is no doubt of the dew-point being far below the actual temperature, that is to say, under conditions where a sheet of wet paper would become dry in a few minutes—over a sandy desert, for instance, where rain never falls, and cloud is a rarity. We may observe, too, that it is only where the purity of the blue sky is most absolute that the polarization is developed in its highest degree, and that where there is the slightest perceptible tendency to cirrus it is materially impaired. Neither is it in the upper regions only that it is effected. The polarized rings are formed, though much more feebly, and under the same conditions of reference to the sun's position below the limit of the visible horizon as above it, provided only the visual ray have a mile or two of air to traverse in full sunshine.

(234.) *Colours of Clouds.*—Whether or no pure air be an absorptive coloured medium, transmitting the blue rays and absorbing the yellow, we may be very sure that the terrestrial matter which, in the form of smoke, dust, and general undefinable impurity, defiles its lower regions, does exercise an absorptive action of a contrary nature, absorbing the violet end of the spectrum and letting pass the red. This is quite sufficient to account for the red and golden hues of sunset, and of those clouds which are high enough to catch the last rays of the declining sun after its disappearance from the horizon of the spectator on the earth. The red, and sometimes greenish, light thrown on the moon by the earth's atmosphere acting as a lens, and concentrating on it light which has undergone its absorptive effect, sufficiently indicates the nature of that absorption on a general average of the whole atmosphere, which, however, is sometimes singularly suspended, and even changed into one of an opposite character, as in the instance of the blue sun seen at Bermuda from 6 A.M. to 5½ P.M. August 13, two days after the great hurricane of August 10, 1831, a phenomenon which Arago has regarded as merely an effect of contrast, but which, described as we happen to have it very circumstantially in a letter from an eye-witness, we must consider to have been an objective reality.

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[1] It did so on the night of the evening referred to. This was after a very hot day, and a series of very dry weather. Repeating the observation the next lunation, after copious rains, no trace of the cross or polarized rings could be anywhere discerned, and the skylight, examined by a doubly refracting prism, showed only a feeble partial polarization in the most favourable position. Perhaps there was unperceived cirrus.

(235.) Professor Forbes, in a very curious paper published in the *Edinburgh Phil. Trans.*, vol. xiv., has shown that high pressure steam, in the act of expansion and while still transparent, is highly absorptive of the violet, blue, and a portion of the green rays of the spectrum; and in a second memoir in the same volume, suggests that without supposing absorptive coloration in the air itself, it may exist in a mixture of air and vapour, the latter being in that peculiar intermediate absorptive state which his experiments have clearly shown under certain circumstances (certainly very remote from atmospheric ones) to exist. Whether the ruddy hues above alluded to in the lower atmosphere be really owing to the presence of absorptive steam, is doubtless a question which may be entertained and more fully discussed; but if the sky be blue by reason of absorption, that absorption must be of a directly opposite character (*i. e.*, most energetic on the red rays of the spectrum).

(236.) *Mirage.*—When the surface of the soil is greatly heated, the air in contact with it is dilated, and while yet supporting the incumbent atmospheric pressure, its elasticity being increased, does so with diminished density. In such a case, rays of light coming from a distant object at great obliquities, before they can reach the ground, are bent upwards by refraction, and pursue their further course as if reflected from the surface of water. Thus, to a spectator receiving both these reflected rays and those which, diverging from the same object, reach his eye directly, having never passed into the heated stratum, both the object and its reflected image will be seen, the one direct, the other inverted, and joined by their bases, as if rising out of a lake of still water, which in arid deserts such a stratum of hot air exactly resembles. Under certain circumstances, on sea coasts, such a layer of hot air (drifted probably from a shore of heated sand) occupies a higher level, and in it, as if in a mirror suspended in the air, the inverted images of ships, mast-head to mast-head with the direct, are seen; and even in some rarer cases, again, another repetition of the image upright above both. Singular instances of this kind are described by Professor Vince as seen at Ramsgate (*Phil. Trans.* vol. lxxxix.) M. Biot has given an elaborate explanation of the theory of such phenomena, in a paper in the *Memoirs of the French Academy*. The accounts of arctic voyages are full of extraordinary exemplifications of the same general principle, where the powerful radiation of an arctic summer sun acts on a surface loaded with ice, and produces great contrasts of local temperature.

(237.) When a current of heated air passes through a body of air generally colder, a lateral mirage is sometimes, though rarely, produced. Thus, on the Lake of Geneva, the image of a boat sailing on it has been seen reflected on such a vertical plane of demarcation. A similar effect is sometimes produced by the sun striking on a wall. We remember when walking on a hot sunny day under the south wall of Kensington Gardens, the sun shining full upon it, to have observed the distinct reflection of persons walking on the same footway. A single soldier for instance appeared as two; the shape and colours of the uniform being visible in the reflected image on the wall, which appeared invested with a glassy, mirror-like coating.

(238.) *Aurora Borealis.*—As a meteorological agent, electro-magnetism, to which department of physics this phenomenon refers itself, has no claim to be regarded. So far as has hitherto been proved, there is no meteorological effect either as regards temperature, moisture, barometric pressure, or wind, which is in the smallest perceptible degree influenced by its most vivid displays. They appear to be developed for the most part in a region of the atmosphere too high, and of too great rarity to affect either our instruments or (except on these occasions) our senses, and the only interest they offer to the meteorologist otherwise than as brilliant spectacles, consists in the evidence which they afford of the existence of *some* matter of inconceivable tenuity no doubt, in those elevated regions capable of being thrown into a luminous state by the passage through it of the electric discharge. Whether electricity passing through an absolute vacuum be luminous, we have no means of determining by experiment, since such a vacuum is beyond our power to produce, though the experiments of Davy would appear to indicate that beyond a certain degree of tenuity (already very extreme) in the gaseous or vaporous medium filling glass vessels admitting of inspection of what passes, the electrical discharge between the poles of a battery not only begins to be less luminous, but the conduction itself is impaired. But in certain phases of an auroral display, indications of a very unequivocal character are afforded of a distribution of material substance in forms which, could they be seen under ordinary circumstances, would be called clouds. We allude to those luminous bands extending across the horizon, and patches of auroral light which are either stationary or nearly so in the sky, but which, when attentively watched, are usually perceived to be slowly drifting southwards, and are generally the precursors of a more active phase of the aurora when it bursts into streamers. These perhaps belong to comparatively less elevated regions, and possibly in some cases to be identifiable with the very highest perceptible cirrous cloud. But besides these, there are others probably at a much greater elevation, and which become perceptible only when traversed by those undulating pulsations of light, converging to the magnetic zenith, which constitute a marked feature of certain auroras. As a flash of what is called sheet-lighting (*i.e.* the reflection of an unseen flash on a distant back-ground of cloud) will often disclose the outlines of intermediate cloud otherwise unsuspected, so these pulsations when carefully watched, will be seen to consist of waves of light traversing regions of space, bounded by more or less definite outlines, within which light is momentarily developed by the passage of each pulse, and whose existence as occupying place and having form, whatever else their nature, is only revealed to us in those moments, not as in the case just alluded to by their projection as intercepting masses on a luminous ground, but as giving off light out of their own substance.

(239.) The height of the auroral arch in that form in which it stretches across the sky as a luminous band at right angles to the magnetic meridian has been estimated on several occasions from its apparent zenith distance as seen from different stations, variously at from 50 to 300 miles above the earth. The most unexceptionable determination seems to have been that of an arch observed simultaneously at Gosport, Keswick, and Newtown-Stewart in Scotland, on Oct. 17, 1819, which, by the calculations of Dalton, *Phil. Trans.* 1828, from the zenith distances observed, was 100 or 102, miles above the earth. It has been suggested that such measurements are inconclusive, on the ground that (as in the case of the rainbow) each observer sees his own arch, and that no one spectator sees the same arch as another. But it is obvious that this applies only to an optical image reflected or refracted from some original source of light elsewhere situated, whereas no one can doubt that the light of the aurora originates nowhere but in the place where it is seen. A planet or comet might with equal justice be considered as the image (formed on some unknown reflector) of some other planet or comet not seen. But the want of absolute fixity in the apparent place of the arc itself is a great obstacle to exactness of determination, as such observations are rarely made at precisely noted and astronomically corrected moments of time. There is very positive evidence, however, that auroral light has been seen below the clouds (as in the Polar Seas by Parry, Sherer, and Ross, on Jan. 27, 1825; near the chain of the Rocky Mountains in North America on December 2, 1850, by Hardisty; and at Alford in Scotland on Feb. 24, 1842, by Farquharson), nay, even habitually seen as if hovering over the Coreen Hills in the last mentioned neighbourhood, at a height from 4000 to 6000 feet (Farquharson, *Phil. Trans.* 1839).

(240.) *Meteors, Shooting Stars,* &c.—The fall of a stone or a shower of stones from the sky would seem at first sight to be quite as fairly entitled to be regarded as a meteorological phenomenon as that of a shower of hail; nay, hailstones are *said* to have fallen, each containing a nucleus of iron pyrites. At all events, falls of stony masses accompanied with aerial detonations and luminous appearances are too numerous and well authenticated to admit of doubt. But there is not the smallest reason to believe that such can be formed in, or anyhow collected from, disseminated particles scattered through the air, and on the contrary, so great a mass of facts go to connect "shooting stars" with astronomical phenomena, that we cannot hesitate in assigning them to that department of physics. This, however, does not apply to a class of meteors of which the great one of August 18, 1783, was an eminent example—great fiery globes, of many hundreds, nay thousands of feet in diameter, evidently not of solid materials, being of fluctuating and continually varying form, and giving out most intense light, many of them being compared not merely to the moon in illuminating power, but to the full light of day. The name Bolis or Bolide has been applied to this class of phenomena. That above mentioned traversed the whole of Europe from the North Sea to Rome, at an altitude tolerably well ascertained of about 50 miles, and with a velocity of from 20 to 40 miles *per second.* Its diameter could not have been less than 4000 feet, having been seen under an angle equal to one-third of the moon's apparent diameter when vertically over the eastern counties of England, from Edgeworthstown in Ireland, at a distance of at least 300 miles. That it must have been a body of extremely small density is evident from the fact of its having made a sudden flexure in its course at a certain point of its progress. There is so much that is enigmatical about these bodies—the trains they leave behind them, and which often remain long visible, and change their aspect and form like luminous clouds; the immense velocity of some, approaching to planetary (yet far short of that of the electric spark), and the complete apparent fixity of others; and their tendency (alleged) to affect the direction of the magnetic meridian (which that of 1783 certainly did)—as to take them out of the domain of exact science. In fact, no theory of their origin, making the smallest approach to plausibility, has hitherto been advanced, though the records of the observations of such meteors would fill volumes, and may be found by consulting the indices of almost every collection of scientific memoirs or notices, and every philosophical magazine and journal. See especially the reports of luminous meteors, from A.D. 338-1293, by Chasles (*Comptes Rendus,* March 15, 1841); the great collection of Chladni; four reports by Prof. Powell to the British Association, 1848-51; two by M. Quetelet to the Royal Academy of Brussels, 1839 and 1842; and Schmidt's *Resultate aus 10-jährigen Beobachtungen über Sternschüppen.*

(241.) *Whirlwinds, Waterspouts, Dust-storms.*—Whenever two currents of air running in opposite directions approach and graze one another, eddies will arise, the air of which, forced into rotation, compressed by its own impulse, and finding no escape downwards or laterally, is driven upwards, and ascends with a vorticose motion, which, as a necessary consequence of the dynamical principle of the "conservation of areas," becomes swifter the nearer the indraughted air approaches the axis of the eddy. Whirlwinds so generated differ widely from cyclones, inasmuch as the ascensional movement is not the cause, but the consequence of the indraught of air; they are whirlwinds of compression, whereas cyclones are whirlwinds of rarefaction. The greater part of those violent and sudden whirlwinds which are confined to limited and linear tracts of land, which carry up into the air haystacks, unroof houses and scatter the materials around, tear off branches of trees, upset boats, and commit other local havoc, are probably of this kind. In such whirlwinds, the law of the direction of rotation which the true cyclone obeys (art. 72) is not necessarily observed, and their rotation may be indifferently direct or retrograde according to the relative situation and direction of the currents from which they originate. They are often terminated by heavy falls of rain, a very obvious consequence of the sudden transfer of a great mass of air nearly saturated with vapour at the surface of the earth to a much higher level (art. 110); for the same reason, that is, that a fall of rain has been not unfrequently observed to follow great natural conflagrations, as in the burning of forests or prairies in North America, or in volcanic eruptions, nay, is even said to have been brought on by fires kindled for that express purpose.

(242.) Whirlwinds of this kind taking place at sea give rise to waterspouts (*trombes de mer*), which are very singular and sometimes dangerous phenomena. Tall columns, apparently of cloud, and reaching from the sea to the clouds, are seen moving majestically along, often several at once, sometimes straight and vertical, at others inclined and tortuous, but always when approached perceived to be in rapid rotation. At their bases the sea is violently agitated, and heaped up with a leaping or boiling motion. Indeed water would seem, at least in some cases, to be actually carried up in considerable quantity, and scattered round from a great height, as solid bodies are on land. Hence they have been supposed by some to draw water from the sea by *suction,* a thing obviously impossible. A notion is prevalent among seamen that they may be cut asunder and dispersed by firing a cannon-shot through them, an effect for which no good reason can be rendered, and which certainly savours of the marvellous. Appendages evidently in the nature of imperfectly formed waterspouts are often seen descending from the under surface of rainy clouds on land (we have such a one before our eyes—August 5, 1857), like long loose tapering tails floating in the air, but not meeting the earth. Viewed through a telescope, they are evidently seen to be hollow vaporous cylinders or conoids—a light medial line or axis being clearly traceable through their whole length, and the rotation perceptible on attending to the slight irregularities in their outline (which is very definite.)

(243.) During the hot season, in parched and sandy tracts of flat country, whirlwinds of an opposite character arise from the ascent of the violently heated air in sheets or streams, determined by accidents of local exposure or by any slight elevation of the soil, up which gliding on all sides, the superficial air becomes concentered for the moment, as we see flames arise and divide themselves. When this takes place on a large scale, a true cyclone may be thus generated; but if the ascensional movement be broken up into numerous partial ascending columns, the wind-flaws which sweep along the surface to feed them, wherever they encounter one another, will from that circumstance alone take on an eddying motion and generate whirlwinds, carrying up with them clouds of dust. These, in the African deserts, often appear as tall columns of sand, revolving and advancing, suffocating and actually overwhelming men and horses, and even armies (as in the memorable expedition of Cambyses into the Lybian desert). That the heat of a wind thus loaded with sand may be insupportable, or even deadly, will be easily conceived when it is remembered that a sandy soil, down to several inches in depth, when undisturbed, may under a tropical sun attain a temperature perhaps exceeding 200° F. (see art. 38), and when suddenly swept up and mingled with air, itself already greatly heated, will communicate its accumulated heat to the general atmosphere, and impart to it, at the same time, a drying power proportioned to its elevation of temperature and absence of vapour. The destructive effects attributed to the Simoom are readily explicable on this view of the causes of its heat, without attributing to it any poisonous quality; and the Simoom itself is not improbably in the nature of a cyclone so originating.

(244.) The "dust whirlwinds" of India, which are very frequent in the district about Lahore and in the Punjab, are sometimes stationary for a long time, sometimes advance with great rapidity. "The sky is clear, and not a breath moving; presently a low bank of clouds is seen in the horizon, which you are surprised you did not observe before; a few seconds have passed and the cloud has half filled the hemisphere, and now there is no time to lose—it is a dust storm, and helter-skelter every one rushes to get into the house in order to escape being caught in it." "A broad wall of dust is observed advancing rapidly, apparently composed of a number of large vertical columns, each preserving its respective position in the moving mass, and each column having a whirling motion of its own." "Precisely the same phenomena in kind are observable in all cases of dust storms, from one of a few feet in diameter to those that extend for fifty miles and upwards." "Their rotatory action seems to be continuous above as far as the eye can reach, and the cloud of dust carried up by them, even at the height of some thousand feet, to possess a gyratory motion." "Towards the close of a storm of this kind a fall of rain suddenly takes place."—*Baddeley on the Dust Storms and Whirlwinds of India.* As might be expected from the powerful friction of the dust on the earth when dragged along and in the act of leaving it, the air in these columns is highly electrical. Mr Baddeley states that during the passage of dust storms, he obtained vivid sparks, and in some cases streams of electricity, from a wire suspended from an insulated bamboo, which would instantly cease on the fall of the terminating shower.

(245.) A vast quantity of solid matter is thus carried up into the higher regions of the air, and no doubt conveyed to great distances, where it sometimes falls, intermingled with rain. Along the west coast of Africa the air is frequently loaded with drifted dust, which covers the decks of ships far out of sight of land. Nay, even on the Peak of Teneriffe, up to the height of 10700 feet, Mr P. Smyth relates that the air during his sojourn on the mountain was very frequently rendered hazy by floating dust, of which there were often several strata, separated by perfectly clear intervals which could be distinctly traced as projected on the distant mountain heights of Palma, far above the uniform cloud-level (described in art. 111) and of such density as totally to obscure the sun previous to his descent below the cloud-level. Showers of fish, frogs, flannel (matted confervæ), bread (edible fungus), infusoria, and other unaccountable substances, are among the more palpable evidences on record of the elevating and transporting power of whirlwinds.

(246.) In conclusion of this essay, which has already extended beyond the limits assigned us, we subjoin a table of the mean values and annual and diurnal average maxima and minima, at a few select stations, of the chief meteorological elements of temperature, pressure, vapour-tension, humidity, and cloud, not as embodying any general climatological results, but in illustration of the main features of meteorological action laid down in the foregoing pages. In the table, to save room, the letters B, P, V, T, H, C, R, are used to denote respectively the total barometric pressure, that of dry air, and that of aqueous vapour or the vapour-tension, the temperature of the air, the degree of relative humidity, the amount of cloud estimated in tenths of the hemisphere covered, and the rain or other aqueous precipitation. Capital letters are used to indicate the annual and monthly means, corresponding to the months of annual maxima and minima, whether simple or multiple, the means for the whole year being entered in the column marked α, and those for the maxima and minima in their order of succession and their epochs, in the subsequent columns β, γ, δ, &c. Similarly for the diurnal march of the same quantities, these are represented by small letters: their means (being identical with the annual means) are not repeated in col. α, but their daily maxima and minima, with their epochs and hours of their occurrence, *reckoned from noon*, occupy the subsequent columns. In the monthly epochs, (1), (2), (3), &c., represent January, February, &c. Where ½ occurs, whether in the indication of the month or the hour, the average moment of the maximum or minimum falls on or about the limit between two consecutive months or hours. These epochs are, however, only approximate. The barometric and vaporous pressures are in English inches, the temperatures in degrees of Fahrenheit's scale, and degrees of humidity and cloud in hundredths of their respective units, viz., complete saturation, and a totally clouded sky.

		α	β	γ	δ	ε	ζ	η	θ	ι
Royal Observatory, GREENWICH. *Lat.* + 51° 31′; *Long.* 0°; *Alt.* 155 *feet.*	B	27·763	29·923	(1½)?	29·627	(3½)?	29·909	(7½)?	29·602	(10)
	P	29·439								
	V	0·324	0·466	(7)	0·195	(1)				
	T	49·27	63·37	(7)	34·20	(1½)				
	H	0·85	0·93	(1)	0·78	(6)				
	C	0·68								
	R	24·40								
	b	...	29·773	22	29·755	4½	29·772	10½	29·752	16
	p	...								
	v	...	0·345	1½	0·303	15½				
	t	...	55·22	1½	44·85	16				
	h	...	0·94	16½	0·75	1½				
	c	...	0·73	0½	0·60	9½				
Mag. and Met. Observatory, TORONTO. *Lat.* + 43° 40′; *Long.* 79° 21′ *W.*; *Alt.* 108 *feet above Lake Ontario.*	B	29·616	29·654	(4)	29·565	(5)	29·675	(9)?	29·587	(2)
	P	29·357	29·508	(12)	29·137	(7)				
	V	0·260	0·489	(8)	0·109	(2)				
	T	44·33	65·77	(7)	23·93	(2)				
	H	0·79	0·85	(11)	0·71	(4)				
	C									
	R	39·69								
	b	...	29·644	22	29·599	4	29·616	10	29·612	16
	p	...	29·389	18	29·316	3				
	v	...	0·287	2	0·231	17				
	t	...	50·31	2	38·93	17				
	h	...	0·86	17	0·69	3				
	c									
Mag. and Met. Observatory, HOBART TOWN. *Lat.* — 42° 52′; *Long.* 147° 25′ *E.*; *Alt.* 105 *feet.*	B	29·781	29·830	(3)	29·669	(11)				
	P	29·478	29·567	(7)	29·349	(11)				
	V	0·302	0·372	(2)	0·247	(7)				
	H	0·76	0·88	(7)	0·65	(12)				
	T	53·48	62·11	(1)	43·73	(7)				
	R	18·40								
	b	...	29·801	21	29·747	3	29·800	9½	29·772	16
	p	...	29·500	19½	29·429	3	29·502	10	29·483	15
	v	...	0·320	1	0·287	16				
	t	...	60·65	2	48·27	17				
	h	...	0·84	16½	0·66	2				
	c									
Mag. and Met. Observatory, LONGWOOD, ST. HELENA. *Lat.* — 15° 57′; *Long.* 5° 41′ *W.*; *Alt.* 1765 *feet.*	B	28·278	28·360	(7)	28·225	(3)				
	P	27·808	27·948	(7)	27·666	(3)				
	V	0·470	0·559	(3)	0·411	(8)				
	T	61·40	66·24	(3)	57·07	(9)				
	H	0·87	0·89	(3)	0·86	(6½)	0·89	(9)	0·86	(1)
	C									
	R	45·2								
	b	...	28·315	22	28·248	4	28·302	10	28·252	16
	p	...	27·838	21	27·770	3	27·835	10	27·795	16
	v	...	0·486	1	0·456	17½				
	t	...	64·86	2	59·31	18				
	h	...	0·91	16?	0·80	2				
	c									
Mag. and Met. Observatory, PETERSBURG. *Lat.* + 59° 57′; *Long.* 30° 28′ *E.*;	B	29·962 ...	30·124 ...	(1) ...	29·813 ...	(2½) ...	30·077 30·119	(4½) (9)	29 846 29·800	(7) (11)
	P	29·734	29·946	(1)?	29·491	(8)?				
	V	0·228	0·441	(8)	0·091	(2)				
	T	39·17	63·07	(7½)	13·75	(2)				
	H	0·82	0·93	(0½)	0·70	(5)				
	R	17·30								
	b	...	29·968	23½	29·960	6	29·969	11	29·948	19
	p	...	29·746	14	29·722	4				
	v	...	0·241	3	0·215	16				
	t	...	42·89	3	35·17	16				
	h	...	0·88	16	0.76	3				
Mag. and Met. Observatory, CATHERINEBURG. *Lat.* + 56° 50′; *Long.* 60° 44′ *E.*;	B	29·036	29·226	(11)	28·827	(6)				
	P	28·851								
	V	0·185	0·425	(7)	0·057	(0½)				
	T	33·37	63·73	(7)	2·00	(1)				
	H	0·80	0·96	(1)	0·62	(5)				
	R	15·60								
	b	...	29·041	21	29 028	3	29·041?	10?	29·037?	17?
	p	...								
	v	...	0·191	2	0·163	16				
	t	...	39·46	2	27·70	15				
	h	...	0·89	16	0·69	2½				

		α	β	γ	δ	ε	ζ	η	θ	ι
Mag. and Met. Observatory, BARNAOUL. *Lat.* + 53° 20′; *Long.* 84° 7′ *E.*;	B	29·593	29.928	(1)	29·232	(7)				
	P	29·404	29·882	(1)	28·792	(7)				
	V	0·189	0·440	(7)	0·046	(1)				
	T	32·45	66·65	(7)	2·79	(1)				
	H	0·77	0·90	(2) ?	0·61	(5)				
	R	10·5								
	b	...	29·603	22	29·587	4½	29·593 ?	7½ ?	29·588	16 ?
	p	...	29·440	17	29·403	3				
	v	...	0·209	1	0·167	16				
	t	...	40·53	2	25·40	16				
	h	...	0·84	16½	0·68	3				
Mag. and Met. Observatory, NERTSCHINSK. *Lat.* + 51° 18′; *Long.* 119° 46′ *E.*;	B	27·783	28·001	(1)	27·580	(7)				
	P	27·622	27·986	(1)	27·129	(7)				
	V	0·161	0·451	(7)	0·015	(1)				
	T	24·46	64·35	(7)	−21·26	(1)				
	H	0·71	0·83	(12)	0·54	(5)				
	R	16·00	4·4 ±	(6½)	0·3 ±	(1)				
	b	...	27·798	21	27·762	3½	27·788	10½ ?	27·785	15 ?
	p	...	27·661	16	27·582	3				
	v	...	0·181	1	0·139	16				
	t	...	32·90	2	17·23	17				
	h	...	0·77	16	0·63	3½				
Mag. and Met. Observatory, PEKIN. *Lat.* + 39° 54′; *Long.* 116° 28′ *E.*;	B	29·946	30·319	(12)	29·533	(7)				
	P	29·629	30·216	(12)	28·754	(7)				
	V	0·317	0·779	(7)	0·087	(1½)				
	T	52·36	82·17	(7)	23·67	(1)				
	H	0·64	0·69 ?	(12) ?	0·49	(5)	0·80	(8)	0·61	(10½)
	R	26·80	9·8	(7½)	0·03	(1)				
	b	...	30·000	21	29·900	4½	29·961	12	29·936	16
	p	...	29·675	20	29·581	5				
	v	...	0·326	1	0·316	5	0·327	8½	0·293	17
	t	...	60·39	2½	45·20	17				
	h	...	0·75	17	0·51	2½				
Mag. and Met. Observatory, SITKA. *Lat.* + 57° 40′; *Long.* 135° 18′ *W.*	B	29·884	30·101	(5)	29.585	(1)				
	P	29·642								
	V	0·238	0·361 ?	(8) ?	0·146 ?	(1)				
	T	41·24	55·30	(7)	26·51	(1)				
	H	0·83	0·87	(2)	0·74	(5½) ?				
	R	87·90	15·0 ±	(10)	1·2 ±	irreg.				
	b	...	29·969	0	29·959	6	29.965	11½	29·957	16
	v	...	0·252	0	0·224	15				
	t	..	45·63	1½	39·91	15				
	h	...	0·85	14	0·75	1				
Mag. and Met. Observatory, TIFLIS. *Lat.* + 41° 40′; *Long.* 42° 50′ *E.*;	B	28·542	28·727	(12)	28·385	(7)				
	P	28·237	28·581	(0½)	27·893	(7½)				
	V	0·305	0·493	(8)	0·145	(1)				
	T	54·78	75·44	(7½)	31·66	(1)				
	H	0·69	0·82	(1½)	0·57	(8)				
	R	19·90	4·1 ±	(7)	0·4 ±	(2)				
	b	...	28·564	21	28·503	4	28·554	13 ?	28·549	16 ?
	p	...	28·264	18	28·198	4				
	v	...	0·314	23	0·294	16				
	t	...	62·26	3	48·85	17				
	h	...	0·80	17	0·54	3				
Royal Observatory, BRUSSELS. *Lat.* + 50° 51′; *Long.* 4° 22′ *E.*; *Alt.* 190 *feet.*	B	29·745	29·844	(12)	29·662	(4)	29·768	(7)	29·681	(9)
	P	29·421								
	V	0·324	0.490	(8)	0·190	(1)				
	T	50·41	64·78	(7)	35·60	(1)				
	H	0·81	0·91	(1)	0·69	(5)				
	C	0·62	0·74	(1)	0·52	(9)				
	R	28·62	3·15	(8)	1·98	(4)				
	b	...	29.754	22	29·734	4	29.753	10	29·736	16
	v	...	0.329	(1)	0·303	16				
	t	...								
	h	...	0·92	16	0·72	2				
	c	...	0·67	1	0·52	12				
Mag. and Met. Observatory, PRAGUE.[1] *Lat.* + 50° 5′; *Long.* 14° 25′ *E.*	B	29·268	29·363	(12)	29·211	(4)	29·325	(9)	29·238	(10)
	P	29·001	29·214	(12)	28·831	(7)				
	V	0·267	0·426	(7)	0·141	(1)				
	T	48·17	67·19	(7)	28·15	(1)				
	H	0·75	0·84	(1)	0·67	(7)				
	C	0·62	0·78	(3)	0·46	(7)				
	R	14·91	2·29	(6)	0·75	(9)	0.97	(11)	0·52	(2)
	b	...	29·284	21½	29·250	4	29·276	11½	29·273	16½
	t	...	53·24	2½	43·65	18				

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[1] These results, deduced from the observations made at the Imperial Observatory, Prague, differ very materially from those given by Herr Karl Fritsch as resulting from the discussion of observations taken in the University Observatory.—(*Grundzüge einen Meteorologic für den Horizont von Prag.*)

		α	β	γ	δ	ε	ζ	η	θ	ι
Mag. and Met. Observatory, BOMBAY, *Lat.* + 18° 58′; *Long.* 72° 56′ *E.*;	B	29·800	29·922	(1)	29·635	(6)				
	P	29·002								
	V	0·798	0·926	(6)	0·617	(2)				
	T	79·40	84·25	(5)	74·40	(2)				
	H	0·79	0·84	(5)	0·74	(2)				
	C	0·36	0·71	(8)	0·01	(1)				
	R	75·20								
	b	...	29·857	21½	29·755	4	29·800	10	29·772	16
	p	...	29·046 ?	22 ?	28·935	4				
	v	...	0·811	22	0·807	1	0·820	4	0·770	17
	t	...	85·00	1	75·00	18				
	h	...	0·96	16½	0·88	0½				
	c	...	0·42	18	0·28	9½				
Girard College, PHILADELPHIA, *Lat.* + 31° 56′; *Long.* 75° 12′ *W.*;	B	29·929	30·024	(2)	29·842	(5)	29·997	(8)	29·906	(10½)
	P	29·573								
	V	0·356	0·645	(7)	0·149	(1)				
	T	51·53	73·27	(7)	28·77	(1)				
	H									
	C	0·61	0·77	(3)	0·45	(6)				
	R	37·25	7·8 ±	(7½)	1·0 ±	(10)	4·9 ±	(11)	0·8 ±	(2)
	b	...	29·960	22	29·897	4	29·939	12	29·926	15
	p	...								
	v	...	0·381	5	0·334	16½				
	t	...	58·33	3	46·00	17				
	h	...								
	c	...	...	1½	...	13½				
Observatory, U. S., WASHINGTON, *Lat.* + 38° 54′; *Long.* 77° 31′ *W.*;	B	30·051	30·147	(1)	29·953	(6)	30·133	(10)	30·060	(12)
	P	29·582								
	V	0·469	0·715	(6)	0·224	(2)				
	T	53·75	75·10	(7)	31·23	(1)				
	H									
	R	41·21	4·5 ±	(1)	2·6 ±	(3)	4·0 ±	(4)	2·9 ±	(12)
MADRID. *Lat.* + 40° 25′; *Long.* 3° 42′ *W.*;	B	27·815	28·003	(3)	27·701	(5)	27·907	(9)	27.624	(12)
	P	27·686								
	V	0·129	0·236	(7)	0·076	(11)				
	T	60·66	82·72	(8)	40·53	(12)				
	H	0·62	0·83	(1)	0·48	(8)				
Office of Ordnance Survey, DUBLIN. *Lat.* + 53° 22′; *Long.* 6° 5′ *W.*; *Alt.* 154 *feet.*	B	29·722	29·793	(5)	29·601	(11)				
	P	29·417								
	V	0·305	0·413	(7)	0·229	(1)				
	T	48·4	58·2	(7)	40·5	(1)				
	H	0·86	0·89	(11)	0·81	(5)				
	R	29·08	3·1 ±	(11)	1·5 ±	(3)				
Radcliffe Observatory, OXFORD. *Lat.* + 51° 52′; *Long.* 1° 15′ *W.*;	B	29·710	29·743	(5)	29·627	(11)	29·763	(12)	29·687	(2)
	P	29·404								
	V	0·306	0·441	(7)	0·218	(2)				
	T	48·60	61·30	(7)	37·0	(1)				
	H									
	R	26·50								
E. J. Lowe, Esq. (BEESTON), NOTTINGHAM. *Lat.* + 52° 57′; *Long.* 1° 8′ *W.*; *Alt.* 174 *feet.*	B	29·774	29·846	(3)	29·764	(6)	29·868	(9)	29·680	(1)
	P	29·473								
	V	0·301	0·438	(7)	0·211	(1)				
	T	47·9	60·5	(7)	38·4	(1)				
	H	0·82	0·88	(12)	0·76	(5)				
	R	26·40								
Sir T. M. Brisbane's Observatory, MAKERSTOUN. *Lat.* + 55° 35′; *Long.* 0° 10′ *W.*; *Alt.* 213 *feet.*	B	29·615	29·718	(5)	29·634	(8)	29·737	(9)	29·547	(1)
	P	29·330	29·436	(5)	29·241	(8)	29·438	(12)	29·235	(1)
	V	0·285	0·393	(8)	0·198	(2)				
	T	46·03	57·00	(7)	36·05	(1)				
	H	0·85	0·90	(0½)	0·79	(6)				
	C	0·70	0·77	(7)	0·61	(12)				
	R	26·35	2·95	(10)	1·36	(4)				
	b	...	29·623	22	29·608	4	29·622	9	29·605	16
	p	...	29·344	11½	29·311	2½				
	v	..	0·301	1	0·267	16				
	t	...	51·19	2	42·07	16				
	h	...	0·92	15	0·75	2				

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J. F. W. H.

METHODISTS, a numerous religious body both in this country and in America. They are divided into several distinct sects; but from the minute shades by which these are distinguished, and the extreme obscurity of some of their numbers, it is difficult to furnish a perfectly accurate account of them. We shall describe those which are best known.

Wesleyan Methodists.

The first in order of time, as well as in point of numbers, is that of *Wesleyan Methodists*. This body derives its name from its principal founder, the Rev. John Wesley. Whilst a student at Christ Church College, Oxford, and engaged in the pursuit of theology, as preparatory to his entering into deacon's orders, Wesley's mind had become strongly imbued with that peculiar asceticism which colours the writings of Thomas à Kempis, Fénélon, William Law, and occasionally of Jeremy Taylor, of whose works he had been a diligent and admiring student. On his assuming the sacred office this tendency was increased rather than diminished; and when, after officiating as curate to his father, who was a clergyman in Lincolnshire, for about two years, he returned to Oxford to resume his duties as a fellow of Lincoln College, it was apparent that it had acquired the complete ascendancy over his mind. His condition at this time was distressing. He felt himself burdened under a sense of guilt in the sight of God, and ignorant of the only way in which that burden could be relieved. Sympathy of feeling and unity of opinion led him to enter into an association which had been formed during his absence among a few of his former friends, in whom a similar course of discipline had produced similar effects. Of this society he soon became the leader and most active member, employing the resources of his comprehensive mind for the regulation of their meetings, and setting an example of diligence in the discharge of every office, and of patience in the endurance of every penance, which in their misguided zeal they had instituted among them, in the hope of thereby obtaining the Divine favour. The regulations which they had adopted for the guidance of their conduct were unusually severe: they were in the habit of partaking of the sacrament every week; they were abstemious in their diet, and plain in their clothing; they had set hours for reading Thomas à Kempis, with meditation and prayer, and for musing on the Passion; they spent much of their time in visiting the prisons and the hospitals; they observed rigidly all the fasts of the English Church, besides a constant abstinence on Wednesdays and Fridays; and in several other respects they exhibited the hold which a morbid asceticism had acquired over their minds. By such conduct, while they commanded the respect of a few, they became the object of ridicule and derision to the many, and had to run the usual gantlope of jokes and nicknames which is destined for all, especially at a university, who are audacious enough to be guilty of innovation either in politics or religion. Of the various titles which the wits of the university devised for them, the only one that has adhered to them is that by which they are now distinguished, viz., Methodists. The author of this appellative is said to have been a fellow of Merton College, who, observing the regularity with which they divided their time among their different pursuits, exclaimed, "Here is a new sect of Methodists sprung up;" alluding to the ancient Methodici, or College of Physicians, at Rome, of whom an account is given by Celsus in the preface to his work *De Medicina*. At this time their members amounted to fifteen, most of whose names Wesley has preserved in his journal. Among the rest are those of James Hervey, the author of the *Meditations*; and George Whitefield, for some time the most efficient assistant, and subsequently the most powerful rival, of Wesley.

The regular formation of this society took place in the year 1729. During the three following years it maintained its ground under the energetic guidance of its head, and increased to the number of twenty-five. In the course of the year 1733, however, Wesley being frequently absent from Oxford, his associates began to lose heart, and to shrink from the persecution which continued to assail them; so that on his return from a visit he had paid to Manchester and other places in that year, he found the members reduced to five. Grieved, but not disheartened, he immediately set himself to repair the loss, but with what success does not appear. His exertions, however, were so great, that, combined with his abstemiousness, they began seriously to affect his health. It is probable that this, together with other circumstances of a private nature, combined with his religious zeal to induce his acceptance of an offer made to him by the trustees of the new colony of Georgia to go out as one of the chaplains of that settlement. This offer was made about the middle of 1735, and towards the close of that year he left England, accompanied by his brother Charles and two other of his Oxford associates, in order to enter upon the duties of his office. On his voyage out he became acquainted with David Nitschman, a Moravian bishop, who, with a party of his followers, was proceeding in the same vessel to join a colony of their brethren already established in the new settlement. From this individual he derived no small advantage in a religious point of view; nor was the insight which he thus obtained into the Moravian institutions and polity without service to him, when in subsequent years he had to assume the office of arranging and legislating for a party of his own.

But Wesley's connection with the Georgian colony was not of long continuance. It was dissolved in 1737, and in the month of February of the following year he arrived in London, a wiser if not a better man than when he had set out. A few months of irregular occupation followed his return; but in September of that year he commenced that course of life in which he persevered till his death, and in the pursuit of which he visited personally the principal places, not only in England, but also in Ireland and in Scotland. The example of his friend Whitefield first induced him to commence field-preaching; a practice which he followed ever afterwards with great success. His brother Charles, who had followed him from America, became a zealous and able coadjutor; and others were speedily added to them. No systematic plan of itinerant preaching seems to have been at first contemplated by them; but their exertions in one place led to their visiting another, and thus a regular course of occasional ministrations was gradually adopted. At first both Wesley and his brother were decidedly opposed to lay-preaching; but the difficulty, or rather the impossibility, of finding individuals who had received orders to supply their rapidly increasing stations, combined with the evidence furnished by one or two remarkable examples, of the possibility of successfully employing individuals who had not been regularly educated for the ministry in itinerant preaching, led to the ultimate adoption of this as a part of their ecclesiastical machinery. An extensive agency was thus called into operation by which the Wesleys were enabled to bear in upon the mass of the people throughout the country, and in consequence very widely to diffuse their principles and augment the number of their adherents. By what steps they advanced it is impossible accurately to detail; but in a very few years they had succeeded in overcoming the persecution by which at first they were everywhere assailed, and in forming societies in all the principal towns and larger villages of England. Over all these Wesley maintained a vigilant watchfulness; and though in general lenient and patient, he yet visited with rigorous discipline those communities or preachers by whom any flagrant departure from the accredited doctrines or practices of the body had been committed. His influence among the societies was maintained partly by frequent visitations, and partly by the power which was concentrated in an annual convention of the preachers, called the Conference, of which he was the moving spring. The first meeting of conference was held in 1744, and this body has regularly held its meetings ever since.

Before Wesley's death Methodism had obtained a considerable footing not only in England and Wales, but in Ireland, America, the West Indies, and to a limited extent also in Scotland. At the time of his death "the number of members in connection with him in Europe, America, and the West India Islands, was 80,000."[1] Since that time this denomination has been making a steadily increasing progress. The number of members in Great Britain in 1853 was 270,265; and they have nearly 6000 chapels, containing accommodation for about a million and a half of persons. The number of their ministers was in 1850, 1034. On census Sunday, 31st March 1851, the attendance at their chapels was,—*morning*, 492,714; *afternoon*, 383,964; *evening*, 667,850. They raise annually upwards of L.145,000 for the support of several religious institutions connected with their body. They have extensive foreign missions on the continent of Europe, in India, Africa, British America, the West Indies, and Polynesia.

The *doctrines* taught by Mr Wesley and his preachers may be technically described as those of evangelical Arminianism. In regard to all the positive doctrines of Christianity he assented, with a few modifications, to the standards of the Reformed churches. He maintained the depravity of human nature; the necessity of an atonement for sin before it can be forgiven; the doctrine of a divine influence to lead men to Christ; justification by faith alone; and the importance of good works, not as the ground of acceptance with God, but as the evidence of faith, and the measure of the final reward. He differed from the system of Calvin chiefly in regard to the extent of the atonement, which he maintained was for all men; to the doctrine of a common grace, which he supposed was given to all, though in various degrees and in different ways;[2] to the opinion that a man who had once believed the gospel might relinquish his belief, and so perish; and to the notion that Christians might obtain salvation from all sin, or entire sanctification, before death. He also held that repentance, which he defined to be "conviction of sin, producing real desires and sincere resolutions of amendment," and fruits meet for repentance, preceded faith; and that the believer has not only the testimony of his own consciousness to persuade him that he is justified, but also the direct testimony of the Spirit of God. These opinions are still retained by the Methodist body.[3]

Of the *polity* of Wesleyanism the fundamental principle is, that all power is centred in the Conference, or annual convention of the clergy. From this body all authority emanates, and by them all regulations to be observed throughout the society are devised and appointed. In their name also are levied all the funds that are required for carrying on the operations of the society, of appointing the individuals who are to superintend the different sections into which the denomination is divided, of assigning to each preacher the station he is to occupy, and of suspending or excluding any member of the community, whom a subordinate jurisdiction, entitled a "Leader's Meeting," may have found guilty of certain faults. All their deliberations being carried on with closed doors, the people at large have no check on their decisions, nor any means of controlling their power: the results of their discussions, however, are published, after each meeting, under the title of Minutes. The management of the body is thus vested entirely in an oligarchy of clergymen, self-elected, and all but entirely uncontrolled. The security of this system is perpetuated by the careful gradation of rank which obtains throughout the whole body of functionaries. The supreme power being vested in Conference, the whole field of Methodism is divided into distinct departments, to which is given the name of Circuits. To each of these as many preachers are appointed as its exigencies may require, and at their head is placed one whose experience and reputation, but especially his fidelity to the cause of Conferential supremacy, entitle him to the distinction, and to whom, under the name of superintendent, the charge of the whole circuit is committed. The appointment of these functionaries is made annually; and no preacher or superintendent can be reappointed to the same place for more than three years successively. Besides these, each circuit has its local preachers, who are generally persons engaged in secular business, but who, having by zeal and ability obtained for themselves the approbation of a local preacher's meeting, are permitted by the superintendent to preach, throughout the vicinity of the place where they reside, in private houses and small country chapels. Out of the number of these the regular preachers are generally chosen, as they have been themselves for the most part chosen from amongst the class-leaders or superintendents of the portions into which each congregation is divided. These classes consist generally of twelve members; and it is the duty of the leader to visit, instruct, and exhort them, as well as to collect their contributions to the funds of the society, and to watch over the correctness of their general conduct. At the meetings of these classes the members state their religious experience, and confess their faults to one another. This, however, is more particularly the object of another subdivision (connection with which, however, is not deemed imperative) called Bands: the members of these are all of one condition in life; that is, the married males meet in one band, the married females in another, and so on. In these bands, which are also under the charge of leaders, there is, in consequence of this arrangement, more freedom of communication, especially in regard to besetting sins and peculiar temptations. Another portion of the members are engaged in the duties of Sunday-school teachers, and are also under the superintendence of a leader. Over all these different agencies it is the duty of the circuit superintendent to watch; and to all of them his word is law. An appeal, indeed, lies from his decision to Conference; but experience has so abundantly shown the uselessness of all such appeals, except in cases of the most glaring nature, that they are hardly ever made.

Whatever objection may be brought against the complication of the machinery of Methodism as opposed to the simplicity of the New Testament, this should not prevent our doing justice to Wesley and his followers by admitting the importance of the services which they have rendered to the cause of religion, education, and morality, throughout the empire. By no denomination of Christians, perhaps, have greater benefits been conferred, in these respects, on the nation at large, than by the Wesleyans. Impelled by an undaunted zeal, they have visited the most abandoned and instructed the most ignorant of the population. Wherever they have gone they have carried the elements of a renovated state of society with them, in the doctrines they have taught and the duties they have inculcated. In many parts of England, where before they commenced their labours the truths of Christianity were as little known as they are in heathen countries,[1] they have succeeded in raising large and active communities, amongst which the effects of Christian teaching are apparent in the good conduct, comfortable circumstances, and increasing respectability of those by whom they are composed. Their zeal has also operated beneficially on other denominations, and has called forth energies that, but for the stimulus of their example, might have continued to lie dormant. In short, it must be confessed that England and America owe an immense debt of gratitude to the illustrious founder of this powerful society; and that the loss of Methodism would be a loss to the world.

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[1] Watson's *Life of Wesley*, p. 378.

[2] See this tenet defended at length in Watson's *Theological Institutes*, vol. ii., p. 258-263.

[3] Watson's *Life of Wesley*, p. 168-199.

Calvinistic Methodists.

Next in order to the Wesleyan Methodists are the *Calvinistic Methodists.* Under this term are included three distinct connections, all of which, however, either arose from, or were greatly strengthened by, the exertions of Whitefield, the original companion of Wesley; and from that circumstance they are sometimes ranked under the name of *Whitefieldians.* Whitefield separated from Wesley shortly after the time when the latter commenced his regular labours as a preacher, upon his return from America. The cause of their separation was their having espoused opposite sides of the Arminian and Calvinistic controversy; Wesley ranking himself with the adherents of the former class of opinions, and Whitefield with those of the latter. This led to their carrying on their itinerant labours independently of each other, though without any attempt on either side to interrupt the peace or the usefulness of the other. Whilst Wesley, however, was skilfully availing himself of his success for the purpose of forming a sect, Whitefield, with less worldly wisdom, contented himself with merely preaching from place to place, and associating himself with any who would acknowledge him as a minister of Christ. At several places, indeed, where he had attracted much attention by his powerful and (to judge from the effects) unparalleled eloquence, he erected chapels, or tabernacles as he called them; but these he invariably left to the care of any evangelical clergyman, whether in the establishment or among the dissenters, whom he saw raised up to occupy them. Since his death the members of these congregations have been nominally, and only nominally, classed together as a distinct body, under the name of the *Tabernacle Connection.* In some of these congregations the service is conducted according to the ritual of the Church of England; whilst in others the order of worship is more in accordance with that observed by the Independents. They all, however, agree in this, that whether there is a settled minister in the place or not, a succession of supplies from the country is kept up throughout the year, each minister being engaged for a month or six weeks at a time. Where there is no settled pastor, the "supply" for the time being discharges the whole duty of the place; where there is a settled pastor the duties are divided between them. The members of this connection have of late years been gradually verging towards the Independents, and it is probable that in a short time both bodies will coalesce.

Amongst the most zealous and devoted of Mr Whitefield's adherents was Selina, Countess of Huntingdon, in whose family he at one time officiated as chaplain. After the death of her husband she employed her ample resources in the erection of chapels in different parts of the country, to the occupation of which she invited at first none but regularly ordained clergymen of the Episcopal Church. Many such accepted her invitation, and laboured in the places she had erected; but finding the supply from this source not adequate to the demand, she founded a college at Trevecca in South Wales, for the education of pious young men of talent for the university. By these means a distinct party was formed, which assumed her name, and is known as *Lady Huntingdon's Connection.* They have upwards of 100 chapels, in all of which the service is conducted strictly according to the ritual of the established church. The attendance on census Sunday was,—*morning*, 21,103; *afternoon*, 4380; *evening*, 19,159. The college has been removed since the death of its foundress to Cheshunt in Hertfordshire, where it is now in a flourishing state.

Another body, which, though not founded by Mr Whitefield, was much strengthened through his means, is that denominated the *Welsh Calvinistic Methodists.* The original founder of this body was Mr Howel Harris of Trevecca. This gentleman had intended to take orders in the Church of England, but was turned from his purpose by what he witnessed amongst the students at Oxford, who seemed to him wholly given to folly and impiety. On his return home he began to preach to his neighbours and in the surrounding parishes. This took place in 1735, and excited no small attention; numbers collected in every place where he preached, to hear him; and ultimately societies were formed, which were placed under the superintendence of experienced individuals. The preaching of Mr Harris was not only successful among the people at large, but was also followed by several clergymen, who at length gave up their livings and united themselves with him. To this party Mr Whitefield lent the aid of his powerful eloquence, and in return received from it many of his most zealous preachers. It was not, however, till the year 1785, when it was joined by the Rev. Thomas Charles of Bala, that, owing mainly to the exertions of that individual, it was organized into a regular body. Since that time its numbers and resources have been steadily increasing both in North and South Wales. It is said that there is hardly a village in the principality where one of its chapels is not to be found. The doctrines held by its members are those of high or hyper-Calvinism. Their form of church government inclines to the Presbyterian, though many practices are encouraged among them that Presbyterians in general would condemn, such as the utterance of exclamations of desire or exultation on the part of the audience during public prayer, jumping and throwing themselves into violent postures under the excitement produced by the preacher's address, and others of a similar kind. They admit also of lay-preaching, and some of their most popular orators are of this class. The sermons of their preachers are generally delivered in a slow recitative, interrupted by quick and startling appeals and interrogations. Even upon those who are ignorant of the language in which the address is uttered, this peculiar mode of delivery is productive of a powerful sensation. It is not surprising, therefore, that on those by whom the whole is understood, and who can enter fully into the highly figurative and impassioned style of sentiment in which the Welsh preachers generally indulge, the most singular effects should be produced. It is no unusual thing to see whole congregations convulsed, and thrown into the most violent agitation, almost instantaneously, by some well-managed appeal to their feelings on the part of the preacher; and this once accomplished, it is not very difficult to keep up the excitement, until both speaker and hearers are ready to sink to the ground from pure exhaustion. The prevalence of this habit cannot but be regretted; but it is characteristic of the people; and though it is doubtless productive of much that is injurious to true piety, it cannot be questioned that upon the whole the labours of these preachers have told most beneficially, as well as extensively, upon the religious and moral improvement of their countrymen. The number of chapels belonging to this body is upwards of 800. The attendance on census Sunday was,—*morning*, 79,728; *afternoon*, 59,140; *evening*, 125,244. The number of ministers in 1853 was 207; of lay-preachers, 234; and of communicants, 58,577.

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[1] "He (Wesley) found thousands of his countrymen, though nominally Christians, yet as ignorant of true Christianity as infidels or heathens." (Bishop Coplestone, as quoted in Watson's *Life of Wesley*, p. 313.)

Other Methodists.

The other classes of Methodists have been produced by secessions from the great body of Wesleyan Methodists. The reason assigned for these secessions has been nearly the same for all, viz., the arbitrary and unconstitutional power assumed by the Conference. The only exception to this is in the case of the *Primitive Methodists*, or *Ranters*, whose ground of secession was, that the true spirit of Methodism was no longer kept up in the body. By this they meant that too much attention was paid to order and decorum in the conduct of public worship; and that sufficient zeal was not manifested in obtruding religion upon the minds of the people by street services, field-preaching, &c. They are less obtrusive now in their methods than at first, but still they occasionally parade the streets, singing hymns, and inviting the populace to their places of worship. They admit of laymen, and even females, being allowed to preach. The number of their chapels in 1853 was 1789, to which are to be added 3565 rooms rented for purposes of religious worship; the number of their preachers was—568 travelling preachers, and 9594 local, besides 6767 class-leaders. The attendance on census Sunday was,—*morning*, 98,001; *afternoon*, 172,684; *evening*, 229,646.

The first secession upon the ground of the unscriptural power exercised by the Conference (and the earliest in point of time of any of the secessions), was made by a party in 1797, very soon after Mr Wesley's death. At the conference held at Leeds that year delegates appeared from many of the societies throughout the country, who were instructed to request that the people might have a voice in the formation of their own laws, the choice of their own officers, and the distribution of their own property. These reasonable demands having been refused, the petitioners agreed to secede from the Conference connection, and to form themselves into a distinct party upon a more liberal basis. The person who took the largest share in prompting and providing for this step was Mr Alexander Kilham, and from him the body thus formed have received the name of *Kilhamites*. They style themselves the *New Connection Methodists*. Their doctrinal views are those of Wesley; but in their polity they seem to have followed in a good measure the forms of Presbyterianism as exhibited in Scotland. The people choose their officers, and appear by representatives at all the synodical meetings of the denomination. This party is not very numerous. In 1853 they had 301 chapels, 95 circuits, 814 local preachers, and about 16,070 members.

Of late there have been several considerable secessions from the general body of the Wesleyans. At least three distinct parties have been formed within a few years. These are—1. The *Bible Christians*, or *Bryanites*, so called from a Mr Bryan, their founder. They differ very slightly from the original Wesleyans, excepting in the admission of the popular element in their scheme of church government. Their ministers preach much in the open air; and females are occasionally allowed to be preachers. In 1852 they had 403 chapels, 113 itinerant ministers, 1059 local preachers, and 13,862 members. The attendance on census Sunday was, *morning*, 14,902; *afternoon*, 24,345; *evening*, 34,612. 2. *The Wesleyan Methodist Association*. This body was formed in 1835 in consequence of the old objection to the Conference, that it exercised tyrannical powers, and unjustly excluded the laity from any share in the management of the body. In 1852 this denomination possessed 329 chapels, 90 itinerant preachers and missionaries, 1016 local preachers, 1353 class-leaders, and 19,411 members. The attendance on census Sunday was,—*morning*, 32,308; *afternoon*, 21,140; *evening*, 40,655. 3. *The Wesleyan Methodist Reformers*. This should hardly perhaps be called a separate body; they are rather a portion of the original Wesleyan Methodists, who have assumed a position of protest against the overbearing authority of the Conference, and of the illegality of their proceedings in the expulsion of certain parties who had censured them. They number about 52,000, and have 2000 places of worship, 2800 preachers, and 3300 class-leaders. On census Sunday the attendance was,—*morning*, 30,470; *afternoon*, 16,080; *evening*, 44,953.

See Southey's *Life of Wesley*; Watson's *Life of Wesley*; Gillies's *Life of Whitefield*; Philip's *Life of Whitefield*; *The Jubilee of the Methodist New Connection*; Mann's *Report on Religious Worship in Great Britain*; Bogue and Bennet's *History of Dissenters*, vol. iii.; and Buck's *Theological Dictionary*, by Henderson. (W. L. A.)

METHODIUS, a famous missionary of the ninth century, was a native of Thessalonica, and was originally a monk in the convent of St Basilius Cyrillus at Constantinople. About 861 he was summoned to Nicopolis by a Christian princess, who was endeavouring to convert her brother Bogoris, King of Bulgaria. That monarch learning that Methodius was an adept in painting, commissioned him to represent the "Pleasures of the Chase." The artist, however, painted the "Last Judgment" with such terrible effect that Bogoris was roused from his indifference, and began to ponder seriously the admonitions he had formerly received from his pious sister. A severe famine that ensued deepened his impressions, and in 863 or 864 he was publicly baptized. Within a short time the majority of his subjects had followed his example. About this period Methodius and his brother Cyrillus went as missionaries to the Sclavonic nation of the Moravians. They began their labours in this new field by constructing a Sclavonic alphabet, and by translating the Scriptures into the Sclavonic tongue. The truth, thus presented in a form that could be received into the minds and hearts of the people, was rapidly disseminated, and in no long time Methodius was consecrated archbishop of the Moravians by Pope Hadrian I. The zeal of Methodius, however, was too intense to be confined within any prescribed limits, and soon began to be exerted in the neighbouring German provinces, which were within the see of the Archbishop of Saltzburg. The German clergy, indignant that a Greek ecclesiastic should encroach upon their jurisdiction, laid their complaint before Pope John VIII., along with a charge against Methodius for using the Sclavonic language in divine worship. The offender was accordingly summoned to Rome in 879; but he pleaded his cause so ably, that the supreme pontiff was convinced of the utility and orthodoxy of his practice, and sent him home to his diocese in 880, with a commendatory letter to Swatopluk, King of Moravia. These favours only intensified the animosity of the German priesthood, and in the following year Methodius again carried his case to the pope. At this date he disappears altogether from history. In after times he was ranked among the saints.

METHODIUS *the Confessor*, Patriarch of Constantinople, was born at Syracuse towards the end of the eighth century, and entered into orders at Constantinople. The patriarch of that city sent him on an embassy to Rome in 820. On his return he was intrusted by Pope Pashalis with a letter upbraiding the Emperor Michael for his harsh persecution of the image-worshippers. Stung by this rebuke, the emperor seized upon the unfortunate messenger, condemned him to suffer 700 lashes, and threw him into a noisome dungeon in one of the islands of the Propontis. There he would have been starved to death had not a poor fisherman contrived to relieve his daily wants. On the accession of Theophilus to the imperial throne, Methodius was released, and raised to high honours in the state. But his irrepressible zeal for image-worship subjected him to a second scourging and a second incarceration in his former dungeon. No sooner had he escaped from this trouble than his private character was assailed by the foulest and the most perilous calumnies. Outliving, however, all these attacks, he was chosen patriarch of Constantinople in 842 by the Empress Theodora, the great patroness of image-worship. The rest of his life was occupied in zealously transferring all the power of the iconoclasts to the image-worshippers. He died in 846. Methodius the Confessor is the author of five orations in praise of monkery, and a collection of *Canones Pœnitentiales*.

METHONE (*Modon*), an ancient city of Messenia, was situated on the S.W. coast. It is called Pedasus in the *Iliad*, and not until the Messenian wars is it mentioned in history as Methone. At the close of the second of these struggles it was given by the victorious Lacedæmonians to the exiled Nauplians, but was restored to its rightful owners by Epaminondas. An unsuccessful attack was made upon Methone by the Athenians in 413 B.C. It was made a free city by the Emperor Trajan.

METIUS, Adrian, an eminent mathematician, was the son of a military engineer, and was born at Alkmaar in Holland in 1571. He studied practical mathematics under his father, law and medicine at the university of Franeker, and astronomy under Tycho Brahe. After visiting Germany, and delivering astronomical lectures there with great success, he returned to Holland to assist his father in his official duties. In 1598 he was promoted to the chair of mathematics at Franeker, a position which he held during the remainder of his life. The degree of M.D. was conferred upon him in 1625. Much of his time and money was latterly spent in the fruitless researches of alchemy. Metius died in 1635. The following is a list of his works:—*Doctrinæ Sphericæ*, 8vo, Franeker, 1598; *Universæ Astronomiæ Institutio*, 8vo, Franeker, 1606; *Arithmeticæ libri duo, et Geometriæ libri sex Practicæ*, 4to, Franeker, 1611; *Praxis Nova Geometrica per usum circini et regulæ proportionalis*, 4to, Franeker, 1623; *De Gemino Usu utriusque Globi*, 4to, Amsterdam, 1611; *Problemata Astronomica Geometrice Delineata*, 4to, Leyden, 1625; *Astrolabium*, 8vo, Franeker, 1626; *Calendarium Perpetuum Articulis Digitorum Computandum*, 8vo, Rotterdam, 1627; and *Opera Omnia Astronomica*, 4to, Amsterdam, 1633

METON, an ancient astronomer, the inventor of the *Metonic Cycle*, was a Leuconian by birth, and flourished at Athens in the fifth century before the Christian era. (See Astronomy.)

METONYMY, the most various of the rhetorical tropes, is the substitution of one word for another when the objects are related as causes, effects, or adjuncts. Thus, in the phrase, "To bring down one's gray hairs with sorrow to the grave," the effect is put for the cause; gray hairs are put for old age. We employ the same figure when we use the author for his writings, the inventor for his invention, &c. This trope was included by Aristotle under the general term metaphor.

METRONOME, from μέτρον, measure, and νόμος, rule, a pendulum which marks the times of music by the slowness or quickness of its oscillations. An instrument of this kind was contrived in France in 1698, and several others followed; but the one which has obtained the preference was constructed in 1812 by the celebrated mechanician J. N. Maelzel, inventor of the panharmonicon, the automaton-trumpeter, &c., and who died in America in August 1838, aged sixty-six. The invention of the mechanical principle of this metronome was publicly and successfully claimed by Winkel of Amsterdam; it being proved that Maelzel had contrived only the scale of numbers applied to the pendulum. The mechanism consists of a vertical rod of steel, which is made to oscillate by clockwork, and of which the oscillations are rendered slower or quicker by means of a weight that slides up and down upon the rod. A scale of numbers, from 50 to 160, but with omissions, *e.g.*, 50, 52, 54, &c., is placed behind the rod or pendulum; 50 representing the greatest degree of slowness, and 160 the greatest degree of quickness of the oscillations in one minute of time. The number 60 will thus represent 60 seconds, and all the other numbers, from 50 to 160, so many fractional parts of a minute; the minute being the integer to which all these subdivisions must be referred. The sliding-weight is raised or lowered upon the rod, so that the oscillations of the pendulum may correspond with this or that number indicated upon the scale; each audible beat or tick of the pendulum forming a fractional part of the minute, but not the two beats produced by the pendulum's motion from one side to the other. The musical notes used in manuscript or printed music, along with the numbers of the metronome scale, to indicate the time of a piece of music, are in general a quaver for an adagio movement, a crotchet for an andante, a minim for an allegro, a semibreve for a presto. For example: adagio, Maelzel's metronome ♪ = 60. It is very desirable that composers should always affix metronome numbers to their compositions. In the latest metronomes the scale ranges from 40 to 208. (See Movement.) (G. F. G.)

METTRIE, Julien Offray de la, a materialistic writer, was the son of a wealthy merchant, and was born at St Malo in 1709. After he had received his classical education at Paris he began his medical studies at Rheims, and finished them under the celebrated Boerhaave at Leyden. In 1742, the Duc de Grammont, colonel of the French guards, appointed him surgeon to his regiment. It was while present in this capacity at the siege of Fribourg, that being attacked with a dangerous sickness, and feeling that his body and mind were enfeebled simultaneously, he drew the inference that the soul must perish along with the organic structure with which it is connected. On his recovery in 1745 he divulged this doctrine in his *Histoire Naturelle de l'Ame*, a book full of the grossest materialism and impiety. The death of his patron at the battle of Fontenoy, in the same year, left him exposed to the storm of indignation that his vagaries had raised. He was expelled from his situation in the guards, and on daring to attack his professional brethren in his *Pénélope, ou le Machiavel en Médecine*, 12mo, 1748, he was driven from his native country. Scarcely had he taken refuge in Leyden when the publication of his revolting opinions in a book entitled *Homme Machine*, 12mo, 1748, subjected him once more to persecution. The work was publicly burnt, and its author was glad to avail himself of an opportune invitation from Frederick the Great to fix his residence at Berlin. The society of wits and philosophers from all parts of Europe, whom the Prussian monarch entertained at Potsdam, received Mettrie with all the distinction and respect due to a victim of intolerance. A pension, the title of reader to the king, and a place in the academy, were conferred upon him. He was admitted to the most intimate familiarity with his master. When he was tired he lounged upon the royal sofas, and when he was over-heated he unbuttoned his vest and threw his peruke upon the floor. At length, however, the brilliant yet no less galling slavery under which the literary dependants of Frederick lived became intolerable to Mettrie. He besought Voltaire, with all the passionate weeping of a child, to obtain for him from the French government leave to return to France; but before that request had time to be granted he was attacked by a severe fit of indigestion. The disorder was aggravated by the absurd treatment he used, and he died in November 1751, deriving no consolation from his own philosophy, or from the maxims of his irreligious associates. After his death his friend Voltaire gave no friendly estimate either of his intellectual or moral character. "Mettrie," said he, "was a fool that never wrote except when intoxicated." The collected works of Mettrie were published in 2 vols., Berlin, 1751.

METZ, a town of France, capital of an arrondissement of the same name, and of the department of Moselle, is situated on both sides of the Moselle, at its confluence with the Seille, 180 miles E.N.E. of Paris, and 80 W.N.W. of Strasburg. The houses are for the most part well built, but the streets are generally narrow, steep, and irregularly laid out. The rivers are lined with quays, and crossed by no less than seventeen bridges. Metz is very well fortified, being the chief defence of the frontier between the Meuse and the Rhine, and, next to Strasbourg, the strongest town in France. The fortifications were constructed by Vauban and Belle-Isle; and the principal forts are Belle Croix, which protects the town on the E., and La Double Couronne on the N. The city is surrounded by walls, in which there are nine gates, only six, however, being actually used. Some of the gates are of great antiquity, having remains of the machinery for raising and lowering the portcullis. The principal building in Metz is the cathedral, a Gothic structure which was begun in the eleventh, but not completed till the sixteenth century; it is in the form of a cross, and is much admired for the boldness and lightness of its architecture. It is about 380 feet in length, and has an elegant spire nearly 400 feet high, from which an extensive and beautiful view may be obtained. Besides this, the church of Notre Dame de la Ronde, and that of the abbey of St Vincent, are remarkable for their antiquity; and the former possesses an ancient episcopal throne and other interesting remains. The military hospital is a large building, erected in the reign of Louis XV., capable of accommodating 1500 patients. Metz contains the largest school of artillery and engineering in France, the pupils of which are chosen from the École Polytechnique of Paris. The town has also a town-hall, court-house containing a large public library, market-house, theatre, barracks, arsenal, &c. The manufactures of Metz consist of woollen and cotton stuffs, hosiery, plush, linen, paper, leather, glue, hardware, cutlery, &c. There is a large gunpowder factory, one of the first in France, on an island in the Moselle. Metz has also a large cannon foundry, the machinery of which is moved by water-power. The trade consists of the articles of manufacture, together with wines, brandy, confectionaries, groceries, &c. Metz is the see of a bishop, and has a court of appeal and tribunals of first instance and commerce. Metz is an ancient town. In the time of Cæsar it was called *Divodurum*, and was the capital of the Gallic nation of the Mediomatrici, from whom, in the fifth century, it took the name of *Mettis*, whence its modern appellation. It is remarkable in ancient history for a massacre of the unsuspecting inhabitants, in a time of peace, by the army of Vitellius, in the year 70 A.D. In the fifth century Metz was destroyed by the Huns. No Roman remains have been discovered in the town; but a short distance to the S. an amphitheatre, baths, and other ruins have been found, which seem to point out this as the exact site of the ancient Divodurum. There are also some remains of the aqueduct by which the town was in ancient times supplied with water. In the middle ages Metz was the capital of the kingdom of Austrasia, but was made by the Emperor Otho II. a free imperial city, and thereafter used by the German emperors as a barrier against France. It was besieged by Charles VII. in 1444, and could only preserve its freedom by the payment of 100,000 crowns. At length Henri II. obtained possession of Metz in 1552; and although it was besieged by Charles V. with an army of 100,000 men, his efforts were completely baffled by the skill and energy of the Duke of Guise, and by the courage and constancy of the townsmen; so that the French continued in possession of the town till it, along with those of Toul and Verdun, was formally secured to them by the peace of Westphalia in 1648. Pop. (1851) 43,484.

METZENSEIFEN (OBER and UNTER), two adjacent villages of Hungary, in the county of Abaujvar, in the territory of Kaschau, and 18 miles W. of that town. The inhabitants are of German origin, and are noted for their industry throughout the country. They are chiefly employed in iron mines and iron works in the vicinity. Pop. (Ober), 1938; (Unter), 3421: total, 5359.

METZINGEN, a town of Würtemberg, circle of the Black Forest, on the Erms, 17 miles S.S.E. of Stuttgart. Wine is produced in large quantities in the neighbourhood; and the town has manufactures of linen and woollen stuffs, leather, &c. A considerable trade in horses, cattle, and agricultural produce is carried on. Pop. 4532.

METZU, GABRIEL, a celebrated Dutch painter, was born at Leyden in 1615. His life seems to have been spent in the unwearied prosecution of his art, and to have been chequered by no more striking events than the successive publications of his numerous pictures. There are indications in his works of a close study of Terburg, Gerard Dou, and Francis Mieris. In the latter part of his life he caught some of the vivacity in execution of his convivial and talented friend Jan Steen. Metzu is generally represented to have died at Amsterdam in 1658; yet some of his well-authenticated pictures bear the dates 1661 and 1667. As a mere imitator of nature, Gabriel Metzu was unsurpassed. His paintings are harmonious combinations of the various qualities of correct design, delicate pencilling, rich and harmonious colouring, and masterly perspective. Conversation-pieces were his favourite subjects. His pictures of sick or fainting ladies, musical parties, letter-writers, morning visits of fashionable gallants, and other scenes in genteel life, are executed with the most refined taste. The same delicate sense of propriety preserves him from all coarseness when he represents a fish-market, a maid-servant sitting in a kitchen with a tabby cat beside her, or a cavalier drinking his beer and smoking his pipe at a cabaret. Very high prices have been given for some of the pictures of Metzu. Some of the most valuable are found in the Louvre, and in the galleries of Berlin, Dresden, and the Hermitage of St Petersburg.

MEURSIUS, or DE MEURS, JOHN, a celebrated antiquary, was born in the year 1579 at Losdun, a town near the Hague. His father, having embraced the Reformed doctrines, took refuge in 1569 at the Hague, and some time afterwards obtained the pastoral charge of Losdun. He taught his son the principles of the Latin language, and then sent him to study at Leyden, where he made so rapid progress, that at the age of twelve he composed harangues in Latin, and at thirteen, verses in Greek. His taste having led him to cultivate philology, he particularly directed his attention to Lycophron, the most obscure of all the Greek authors, whom he undertook to illustrate; and at the age of sixteen he completed his commentary on that difficult writer, a work which astonished the greatest scholars and critics of the time. When he had finished his course of study, the grand pensionary Barneveld confided to him the education of his sons; and he was also appointed to accompany them to the different courts of Europe. He turned his travels to account by availing himself of the opportunities which they afforded for extending his knowledge; and in passing through Orleans in 1608 he was honoured with the degree of Doctor of Laws. On his return to Holland in 1610 he was appointed professor of history in the academy of Leyden; and the following year he was promoted to the chair of Greek, which he filled with great distinction. The states of Holland conferred on him the title of historiographer, and honoured him with other marks of their esteem; but after the execution of Barneveld in 1619, Meursius was innocently subjected to much persecution from his connection with that unfortunate man. But the King of Denmark came to his relief in 1625, and offered him the chair of history in the university of Sora, together with the place of historiographer, a situation which he at once accepted. The remainder of his life was divided between his official duties and literary pursuits; and he died on the 20th of September 1639, at the age of sixty.

The memory of Meursius has suffered by his being sometimes represented as the author of the infamous dialogues *De Arcanis Amoris et Veneris.* This licentious work, it is now well known, was the production of one Chorier, an advocate of Grenoble, who probably prefixed to it the name of Meursius for the purpose of throwing ridicule on the grave and learned professor. His son John was a scholar of considerable eminence, and produced some works evincing erudition and research.

Meursius rendered a most valuable service to letters by the numerous annotated editions which he published of the Greek authors. The principal works which he edited are,—the *Poems* of Lycophron; the *Tactics* of the Emperor Leo; the *Opuscula* of Hesychius; the *Elements of Music* by Aristoxenes; the *Letters* of Philostratus; the *Historia Lausiaca* of Pallades; the *Annals* of Manasses; the *History* of Theodosius Metochites; the *Tactics* of Constantine Porphyrogennetes; the *Marvellous Histories* of Phlegon Trallianus, Antigonus Carystius, and Appollonius Dyscoles; and the works of Porphyry, Procopius, Gaza, and others. The works of Meursius were collected by Lami, Florence, 1741–1763, in 12 volumes folio. This collection is rare and much prized. In the *Mémoires* of Niceron (tom. xii. and xx.) will be found a list of all the productions of this indefatigable writer, in number sixty-seven; but we shall here only indicate those which are most deserving of the attention of the curious. *Glossarium Græco-Barbarum*, Leyden, 1614, in 4to; a work which, in regard to the Greek writers of the Lower Empire, holds the same place as the Glossary of Du Cange does for the writers of the corresponding age of Latinity. Various treatises on different departments of Greek and Roman antiquities, for the most part reprinted in the *Thesaurus* of Grævius. *Rerum Belgicarum Liber Primus*, Leyden, 1612; *Historia Danica*, Copenhagen, 1630.

MEURTHE, a department of France, bounded on the N. by that of Moselle, E. by that of Bas Rhin, S. by that of Vosges, and W. by that of Meuse. It lies between Lat. 48. 20. and 49. N., Long. 5. 40. and 7. 20. W.; having a length of 70 miles, an average breadth of 35, and an area of 2353 square miles. The eastern part of the department is occupied by the Vosges Mountains, which rise to the height of 1148 feet; and the rest of the surface is diversified and undulating, being traversed by numerous low spurs of the same mountain range.

The principal river is the Moselle, which traverses the department in an irregular course from S. to N., and is joined near Nancy by the Meurthe, from which the department takes its name. The former of these rivers is navigable in this department for 21 miles, and the latter for 6. The department is also watered by the Seille and the Sarre, smaller tributaries of the Moselle; and it contains several lakes of small size. The nature of the soil is very various in different parts; but it is in general of great fertility, especially in the valley of the Seille. Of the whole area of 1,505,928 acres, 750,000 acres consist of arable land; 175,000 of pasturage; 40,000 of vineyards; 290,000 of wood; 15,000 of waste land; &c. The quantity of wheat annually raised is about 3,240,000 bushels; and the amount of wine produced in ordinary years is 20,064,000 gallons, but its quality is by no means so remarkable as its quantity. Potatoes also, and leguminous plants, thrive well here; flax and rape are cultivated largely; and the hay furnished by the meadows of this department is of great excellence. The horses and cattle of Meurthe are not remarkable for the excellence of their breed; but pigs are reared in large numbers and with considerable success. The number of horses is about 75,000; of cattle, 92,000; of sheep, 180,000; and of pigs, 110,000; large numbers of which are exported. The mineral productions are not of much importance. They consist principally in rock-salt and salt springs, from which upwards of 44,000 tons of salt and nearly 1000 tons of soda are annually obtained. There are also numerous quarries of marble, granite, limestone, slate, &c., and a small amount of iron ore has been found, but not so much as to render the working of iron mines a profitable undertaking. The principal branches of industry prosecuted here are the manufacture of iron and glass; but those of lace, cotton and woollen stuffs, paper, glue, &c., are also carried on. The manufactures were formerly in a very low condition, but of late years they have increased greatly in prosperity. The commerce of the department consists chiefly in the productions of the agricultural and manufacturing industry of the inhabitants. The people of Meurthe are partly of French and partly of German origin, and the German language is still spoken in the east of the department.

The railway from Paris to Strasbourg runs through the department for a distance of more than 80 miles. Meurthe is divided into five arrondissements, as follows:—

	Cantons.	Communes.	Pop. (1851.)
Nancy	8	187	147,978
Château-Salins	5	147	68,634
Lunéville	6	145	88,978
Sarrebourg	5	116	76,667
Toul	5	119	68,166
Total	29	714	450,423

The total population in 1856 was 424,373. The capital is Nancy.

MEURTHE, a river of France, rises near Mount Bonhomme, a summit of the Vosges range, in the department of Vosges, flows N. and N.W. through that department and the adjoining one of Meurthe, and after a course of 100 miles, falls into the Moselle below Nancy. It receives the Vezouze and the Mortagne; and is navigable as far up as Nancy, about 6 miles from its confluence with the Moselle. It frequently overflows its banks, and thus contributes greatly to the fertility of the surrounding country. Large quantities of timber are floated down this river. The chief towns on its banks are St Dié, Raon l'Etape, Lunéville, and Nancy.

MEUSE, a department of France, bounded on the N. by Belgium and the department of Ardennes, E. by those of Moselle and Meurthe, S. by those of Vosges and Haute-Marne, and W. by those of Marne and Ardennes; lies between 48. 25. and 49. 35. N. Lat., and between 4. 54. and 5. 50. E. Long.; having a length of 83 miles, a breadth of 40, and an area of 2436 square miles. The department is traversed by two ranges of mountains at no great distance from each other, which extend from the Faucilles in the S. to the hills of Ardennes in the N. The highest summit of these ranges does not exceed 1600 feet; and between the two lies the valley traversed by the Meuse, from which the department takes its name. The other parts of the department present a great variety of hills, valleys, and plains. Besides the Meuse, it is watered by the Aisne and its tributary the Aire; by the Ornain and the Saulx, which join the Marne; by the Madine and Orne, tributaries of the Moselle; and by the Chiers, which falls into the Meuse. The nature of the soil is as varied as that of the surface of the country; and in some parts, especially in the valleys, it is rich and fertile, but in the hills and plains it is in general thin and poor. Of the whole area, 875,000 acres consist of arable land; 325,000 of wood; 125,000 of meadow land; 35,000 of vineyards; &c. The quantity of grain produced is more than enough for the supply of the inhabitants; potatoes, pease, beans, flax, &c., are also largely cultivated, and with great success. The fruits are excellent; gooseberries in particular are raised with much care; and the wines of Meuse, especially those of the valley of the Ornain, are highly prized. The pasturage is very good; and the cattle are superior to those of the neighbouring country. The horses are weak and small; but the rearing of pigs is attended to with much care. It is computed that the department contains 60,000 horses, 96,000 cattle, 214,000 sheep, 98,000 pigs, &c. The principal minerals in the department are iron, good building stone, potters' clay, and slate. The inhabitants are employed to a great extent in iron mines, forges, lime-kilns, glassworks, potteries, cotton factories, paper-mills, &c.; and the trade consists of iron, timber, wines, cotton stuffs, salt provisions, &c. The railway from Paris to Strasbourg runs through this department for a distance of 42 miles. Meuse is divided into four arrondissements, as follows:—

	Cantons.	Communes.	Pop. (1851.)
Bar-le-Duc	8	128	86,358
Commercy	7	180	87,664
Montmédy	6	131	69,096
Verdun	7	149	85,539
Total	28	588	328,657

In 1856 the total population was 305,727. The capital is Bar-le-Duc.

Meuse (anciently *Mosa*, Flemish *Maes*, Dutch *Maas*), a river of Europe, which takes its rise in the plateau of Langres, being formed by the union of two small streams above the village of Meuse, in the department of Haute-Marne. It flows northward in a narrow valley across the departments of Vosges, Meuse, and Ardennes, till it enters Belgium. At Namur it takes a N.E. direction; then separates Dutch from Belgian Limburg, and enters Holland; then turns to the N.W., and afterwards to the W. At a short distance below Gorcum it divides into two arms, the northern of which gets the name of Merwe, and again divides into the Maas and the Oude-Maas, or Old Meuse, inclosing between them the island of Ysselmonde, and falling among shoals and quicksands into the German Ocean. The other arm of the Meuse, flowing farther to the S., also separates into two smaller streams, one of which, called Haring-Vliet or Herring Stream, and afterwards Flakkee, separates the islands of Voorn and Over-Flakkee, and falls by a wide estuary into the ocean; and the other enters the sea farther S., between the islands of Over-Flakkee and Schouwen, communicating also by a smaller branch with the estuary of the Schelde. The whole length of the Meuse is about 550 miles; but a direct line from its source to its mouth would not exceed 230 miles in length. It is navigable as far as Verdun, a distance from the sea of 430 miles, of which nearly 300 are in Holland and Belgium. In the upper part of its course the river flows through a narrow valley, where the scenery is wild and picturesque, the precipitous cliffs sometimes leaving only a narrow defile, through which the river flows. In the lower part the appearance of the country is of a very different nature. Here there stretch large plains, which were originally under water, but have been recovered by the laborious and persevering efforts of the Dutch. The delta formed by the Meuse is greater than that of any other river in Europe. The Meuse receives in France the Monzon, the Vair, and the Chiers; in Belgium the Sambre, the Lesse, and the Ourthe; in Holland the Roer, the Niers, and the Rhine, by its three branches the Waal, the Leck, and the Yssel. The principal towns on the Meuse are,—Neufchâteau, Verdun, Sedan, Charlemont, and Givet, in France; Namur and Liège in Belgium; and Maestricht, Venloo, Grave, Gorcum, Willemstad, and Rotterdam, in Holland.

MEUSEL, Johann Georg, was born in 1743 at Eyrichshof, near Bamberg in Bavaria. After having received his education at Coburg, he went to the university of Göttingen, where he was appointed a member of the historical institute and of the philological seminary. Professor Klotz being appointed to a chair in Halle, invited Meusel thither, and there he remained till he obtained the chair of history at Erfurt in 1769. In 1780 he was appointed to the same chair in Erlangen, where he remained till his death in 1820. He is chiefly famous for his industry and accuracy in the collection of facts; but his histories are rather inferior productions, as he seems to have been oppressed with the weight of his extensive learning and the vast amount of his materials. His principal works are,—*Gelehrtes Deutschland*, Lemgo, 1796–1806, in 12 volumes; *Lexicon der von* 1750–1800 *Verstorbenen Schriftsteller*, Leipsic, 1812–1816, in 15 volumes; *Anleitung zur Kenntniss der Europaischen Staaten Historie*, Leipsic, 1816; *Literatur der Statistik*, Leipsic, 1806–7, in 2 volumes; and *Lehrbuch der Statistik*, Leipsic, 1805.

MEXICO.

I.—HISTORY OF MEXICO FROM THE EARLIEST ACCOUNTS TILL ITS SUBJECTION TO SPAIN.

Mexico, a republic of North America, is situated between 16. and 33. N. Lat., and between 86. and 117. W. Long.; being nearly 2000 miles in length, and 1100 miles in greatest breadth.

Toltecans the first inhabitants.

The Toltecans are the most ancient Mexican nation of which we know anything. They were expelled from their own country, which is supposed to have been *Tollan*, to the northward of Mexico, in the year A.D. 472. After leading a wandering life for 104 years, they reached a place about 50 miles to the eastward of the city of Mexico, where they settled for 20 years, giving to their new residence the name of *Tollantzinco*. From thence they proceeded about 40 miles farther to the west, where they built a city, called, from the name of their country, *Tollan* or *Tula*.

After the final settlement of the Toltecans, the government became monarchical. Their first king began his reign in 667, and their monarchy lasted 384 years. During this time they reckon only eight princes, as it was a custom amongst them to continue the name of each king for fifty-two years from the time when he ascended the throne. If he died within that period, the government was carried on in his name by regency; and if he survived, he was obliged to resign his authority. During the four centuries that the monarchy continued the Toltecans increased very considerably in number, and built many cities; but when in the height of prosperity almost the whole nation was destroyed by a famine occasioned by drought and a pestilence. The few who survived abandoned the country of Tula about 1051.

Succeeded by the Chichemecas.

A century later they were succeeded by the Chichemecas, a much more barbarous people, who came from an unknown country called *Amaquemecan*, where they had for a long time resided. The motive of the Chichemecas for leaving their own country is not known. They were eighteen months on their journey, and took possession of the desolate country of the Toltecans about 100 years after the famine. Though much more uncivilized than the Toltecans, they had a regular form of monarchical government, and in other respects were less disgusting in their manners than some of the neighbouring nations. Their king, Xolotl, chose for his capital Tenayuca, about 6 miles to the northward of the city of Mexico, and distributed his people in the neighbouring territory; but as most of them went to the northward, that part obtained the name of the country of the Chichemecas, in contradistinction to the rest. Xolotl finding himself peacefully settled in his new dominion, sent one of his officers to explore the sources of some of the rivers of the country. Whilst performing this task he came to the habitations of some Toltecans, who, it seems, had still kept together, and were likely once more to become a nation. As these people were not inclined to war, and were greatly esteemed for their knowledge and skill in the arts, the Chichemecas entered into a strict alliance with them, and Nopaltzin, the son of Xolotl, married a Toltecan princess. The consequence of this alliance was the introduction of the arts and knowledge of the Toltecans amongst the Chichemecas.

New inhabitants.

When Xolotl had reigned about eight years in his new territories, an embassy of six persons arrived from a distant country not far from Amaquemecan, expressing a desire of coming with their people to reside in the country of the Chichemecas. The king gave them a very gracious reception, and assigned them a district; and, in a few years afterwards, three other princes, with a great army of Acolhuans, who were likewise neighbours of Amaquemecan, made their appearance. These, also, Xolotl allowed to settle in his country, and gave in marriage his two daughters to two of the kings, and a noble virgin of Chalco to the third. As the Acolhuans were the more civilized nation of the two, the name of Chichemecas began to be appropriated to the more rude and barbarous portion, who preferred hunting to agriculture, or a life of savage liberty in the mountains to the restraints of social laws. These barbarians associated with the Otomies, another savage nation who lived to the northward; and by their descendants the Spaniards were harassed for many years after the conquest of Mexico.

Dominions of Xolotl divided.

As soon as the nuptial rejoicings were over, Xolotl assigned a portion of his territories to each of the three princes. Acolhuatzin, who had married his eldest daughter, had Azcopazalco, 18 miles to the westward of Tezcuco; Chiconquauhtli, who had married the other, received a territory named Xaltocan; and Tzontecomatl, who married the lady of inferior rank, obtained one named Coatlichan. The country continued for some time to flourish, population increased greatly, and with it the civilization of the people; but as these advanced, the vices of luxury and ambition increased in proportion. Xolotl died in the fortieth year of his reign, at a very advanced age.

Nopaltzin, the second king.

Xolotl was succeeded by his son Nopaltzin, who at the time of his accession is supposed to have been about sixty years of age. In his time the tranquillity of the kingdom, which had begun to suffer disturbance under his father, experienced much more violent shocks, and civil wars took place. The whole province of Tollantzinco rebelled, and the king himself was obliged to take the field. As the rebels were very numerous, the royal army was at first defeated, but at length the insurgents were overcome, and their ringleaders severely punished. The king did not long survive the restoration of tranquillity to his dominions. He died in the thirty-second year of his reign and ninety-second of his age, leaving the throne to his eldest son Tlotzin, who was an excellent prince, and reigned thirty-six years.

Quinatzin. Disturbances in various parts.

Quinatzin, the son and successor of Tlotzin, was vain and luxurious. His reign, though tranquil at first, was soon disturbed by dangerous revolts and rebellions. These first broke out in two states, named Maztillen and Totopec, situated amongst the northern mountains. The king having collected a great army, marched without delay against the rebels, and after frequent engagements for the space of forty days, gained a complete victory, and punished the ringleaders of the defection with great severity. Tranquillity, however, was not yet restored; the rebellion spread to such a degree that the king was obliged not only to take the field in person, but to employ six other armies, under the command of faithful and experienced generals, in order to reduce the rebels. These proved so successful in their enterprises, that in a short time the rebellious cities were reduced to obedience, and the kingdom enjoyed the blessings of peace during the long reign of Quinatzin, who is said to have sat upon the throne for no less than sixty years. He was succeeded by his son Techotlatla; but as the affairs of the Acolhuans had now begun to be connected with those of the Mexicans, it will be proper to give some account of that people.

Migrations of the Mexicans, A.D. 1160.

The nation of the Aztecas, which comprised the Mexicans, dwelt till the year 1160 in a country called *Aztlan*, situated to the N. of the Gulf of California, as appears by the route they pursued in their journey, but how far to the northward we are not certainly informed. Betancourt makes it no less than 2700 miles, and Boturini says it was a province of Asia. The Aztecas, when they left their original habitations, were divided into six tribes; but at Culiacan the Mexicans were left with their god (a wooden image), while the five tribes of Xochimilcas, Tepanecas, Chalcese, Tlahuicas, and Tlascalans, continued their march. The remaining tribe was divided into two violent factions, which persecuted one another, but always travelled together in order to enjoy the company of their god. At every place where they stopped an altar was erected to him; and at their departure they left behind them all their sick, and probably also all that were not willing to endure the fatigue of such journeys. They stopped in Tula nine years, and eleven more in the neighbouring parts. At last, in 1216, they arrived at Zumpanco, a considerable city in the valley of Mexico, and were received in a hospitable manner by the lord of the district. He not only assigned them proper habitations, but even demanded from amongst them a wife for his son Ilhuicatl. This request was complied with, and from this marriage all the Mexican kings descended.

Persecution of the Mexicans, A.D. 1245.

The Mexicans continued to migrate from one place to another along the Lake of Tezcuco. Xolotl, who was then on the throne of the Acolhuans or Chichemecas, allowed them to settle in whatsoever places of his dominions they thought proper; but some of them finding themselves harassed by a neighbouring lord, were obliged in the year 1245 to retire to Chapoltepec, a mountain on the western borders of the lake, scarcely two miles distant from the site of Mexico. This took place in the reign of Nopaltzin, when disturbances began to take place in the Acolhuan dominions. The Mexicans, however, did not find themselves any more secure in their new place of residence than formerly. They were persecuted by the neighbouring lords, and obliged to take refuge in a number of small islands, named Acocolco, at the southern extremity of the Lake of Mexico. Here for fifty-two years they lived in the most miserable manner, subsisting on fish, insects, roots, &c., and clothing themselves with the leaves of the amoxtli, which abounds in that lake. In this miserable plight the Mexicans continued till the year 1314, when they were reduced to a state of the most absolute slavery by the king of a petty state named Colhuacan. After some years a war broke out between the Colhuans and Xochimilcas, in which the latter gained such advantages that the former were obliged to employ their slaves to assist them. The Mexicans, armed with long staves having their points hardened in the fire, with knives of the stone itztli, and with shields of reeds woven together, harassed the enemy so much by not making any prisoners, but by uniformly cutting off the ear, that the Colhuans gained a complete victory. Notwithstanding, it does not appear that the haughty masters were in the least inclined to afford their slaves easier terms than before. On a certain day, which the Mexicans had set apart for sacrificing to their god, the Colhuan prince attended with his nobility, not with a view to do honour to the festival, but to make a mockery. Their derision, however, was soon changed into horror, when the Mexicans, after a solemn dance, brought forth four Xochimilcan prisoners; and after having made them dance, cut open their breasts with a knife, and plucking out their hearts, offered them, whilst yet palpitating with life, to their sanguinary idol. This had such an effect upon the spectators, that both the king and his subjects desired the Mexicans immediately to quit their territories and go where they pleased. This order was instantly obeyed. The whole nation took their route towards the north until they came to a place named *Iztacalco*, near the site of Mexico.

City of Mexico founded, A.D. 1325.

The city of Mexico was founded in 1325 on a small island named Tenochtitlan, in the middle of a great lake, without ground to cultivate for subsistence, or even room sufficient to build habitations. To enlarge the boundaries of their island, they drove palisades into those parts of the water which were most shallow, terracing them with stones and turf, and uniting to their principal island several other smaller ones which lay in the neighbourhood. The greatest effort of their industry, however, was the construction of floating gardens, by means of bushes and of the mud of the lake; and these they brought to so much perfection that they produced maize, pepper, chia, French beans, and gourds. During the thirteen years that the Mexicans had to struggle with extreme difficulty they remained at peace; but no sooner did they begin to prosper and live comfortably, than the inveterate enmity between the two factions broke out in all its fury. This produced a separation; and one of the parties took up their residence on a small island at a little distance to the northward, which, from a heap of sand found there, they at first named *Xaltilolco*, but afterwards *Tlatelolco*, from a terrace constructed by themselves. This island was afterwards united to that of Tenochtitlan. About this time the Mexicans divided their city into four parts, each quarter having now its tutelar saint, as it had formerly had its tutelar god. In the midst of their city was the sanctuary of their great god *Mexitli*, whom they constantly preferred to all the rest. To him they daily performed acts of adoration; but instead of making any progress in humanity, they seem to have daily improved in the most horrible barbarities, at least in their religion.

Acamapitzin, the first king of Mexico, A.D. 1352.

In the year 1352 the Mexican government was changed from an aristocracy to a monarchy. At first the people were governed by twenty lords, of whom one had an authority superior to the rest. This naturally suggested the idea of monarchy; and to this change they were also induced by the contemptible state in which their nation still continued, thinking that the royal dignity would confer upon it a degree of splendour which otherwise it could not enjoy, and that by having one leader, they would be better able to oppose their enemies. Proceeding, therefore, to elect a king, the choice fell upon Acamapitzin, a man held in great estimation amongst them, and descended from Opoclitli, a noble Aztecan, and a princess of the royal family of Colhuacan. As he was yet a bachelor, they negotiated a marriage with the daughter of Acolmiztli, lord of Coatlichan, and the nuptials were celebrated with great rejoicings. In the meantime the Tlatelolcos, the natural rivals of the Mexicans, likewise chose a king. Not thinking proper, however, to choose him from amongst themselves, they applied to the king of the Tepanecos, who readily sent them his son; and he was crowned first king of Tlatelolco in 1353. In this the Tlatelolcos seem to have had a design of humbling their rivals, as well as of rendering themselves more respectable; and therefore it is very probable that they had represented the Mexicans as wanting in that respect due to the Tepanecan monarch, from having elected a king without his leave, though at the same time they were tributaries to him. The consequence of this was, that he doubled their tribute, and imposed upon them many whimsical tasks. They freed themselves, however, from all their difficulties by vigorous exertions, absurdly ascribing to the malevolent being whom they worshipped all the glory of every deliverance. Acamapitzin governed this city, which at that time comprehended the whole of his dominions, for thirty-seven years in peace.

Huitzilihuitl, the second king, A.D. 1389.

Acamapitzan died in the year 1389, lamented by the Mexicans, and his death was followed by an interregnum of four months. As the deceased monarch had formally resigned his authority into the hands of his nobles, it was necessary that a new election should take place; and the choice fell upon Huitzilihuitl, the son of Acamapitzin. The new monarch began his reign by espousing the daughter of the King of Azcapozalco. Though this princess brought him a son the first year of their marriage, the king, in order to strengthen himself by fresh alliances, married also the daughter of another prince, by whom he had Montezuma Ilhuicamina, the most celebrated of all the Mexican kings. As the Mexicans advanced in wealth and power so did their rivals the inhabitants of Tlatelolco. Their first king died in 1399, leaving his subjects greatly improved in civilization, and the city much enlarged and beautified. The rivalship which subsisted between the two cities had indeed greatly contributed to the aggrandizement of both. The Mexicans had formed so many alliances by marriage with the neighbouring nations, had so much improved their agriculture and floating gardens on the lake, and had built so many more vessels to supply their extended commerce and fishing, that they were enabled to celebrate their secular year, answering to the year 1402 of our era, with far greater magnificence than they had ever done since they left their original country of Atztlan. In 1406 Techotlala, King of Acolhuacan, died, after a tranquil reign of thirty years. No sooner had his son Ixtlilxochitl succeeded him than the Kings of Mexico, Azcapozalco, and Tlatelolco abjured their allegiance. After a disastrous contest of three years, the rebels, designing to accomplish by treachery what they had been unable to effect by force, sued for peace and obtained it.

Chimilpopoca, third king of Mexico, A.D. 1409.

In 1409 died Huitzilihuitl, King of Mexico, who left the right of electing a successor to the nobility. They made choice of his brother Chimilpopoca; and hence it became an established law to choose one of the brothers of the deceased king, or, if he had no brothers, to elect one of his grandsons. Whilst the new prince was endeavouring to secure himself on the throne, the treacherous Tezozomoc, King of Azcapozalco, employed all the means in his power to strengthen the party he had formed against the King of Acolhuacan. In this he had such success, that the unfortunate prince found himself reduced to the necessity of wandering amongst the neighbouring mountains, at the head of a small army, accompanied by the lords of Huexotla and Coatlichan, who remained faithful to him. The Tepanecans, by intercepting his provisions, distressed him to such a degree that he was forced to beg them of his enemies. At length they killed him, after they had treacherously persuaded him to hold a conference with two of their captains. This perfidious act was committed in sight of the royal army, who were too weak to revenge it. The royal corpse was saved with difficulty; and Nezahualcojotl, the heir-apparent to the crown, was obliged to shelter himself amongst the bushes from the fury of his enemies.

Acolhuacan conquered by Tezozomoc.

Tezozomoc having now in a great measure gained his point, proceeded to pour down his troops upon those cities and districts which had remained faithful to the late unfortunate monarch. The people made a desperate defence, and killed great numbers of their enemies; but at last being reduced by the calamities of war, and in danger of total extermination, they were obliged to quit their habitations and flee to other countries. The tyrant then gave Tezcuco to Chimilpopoca, King of Mexico, and Huexotla to Tlacacotl, King of Tlatelolco; at the same time placing faithful governors in others places, and appointing Azcapozalco, the capital of his own territory, the royal residence and capital of Acolhuacan. All the rest of the Acolhuacan empire submitted; and Nezahualcojotl saw himself for the present deprived of all hopes of obtaining the crown. Tezozomoc had now attained the summit of his ambition. But instead of conciliating the minds of his new subjects, he oppressed them with fresh taxes; and being conscious of the precarious situation in which he stood, and tormented with remorse on account of his crimes, he fell into melancholy, and at length expired in the year 1422, leaving the crown to his son Tajatzin.

The throne usurped by Maxtlaton, A.D. 1422.

Tezezomoc was no sooner dead than Maxtlaton, one of his other sons, without paying the least regard to his father's will, began to exercise the functions of sovereign, and compelled his brother Tajatzin to retire to Chimilpopoca, King of Mexico. This monarch, agreeably to the character of that age and people, advised him to invite his brother to an entertainment, and then to murder him. Unluckily for both, this discourse was overheard by a servant, who, in expectation of a reward, informed the tyrant of what he had heard. Maxtlaton therefore determined to rid himself of his brother without delay. This he soon accomplished in the very same way that had been projected against himself. Tajatzin, along with the Kings of Mexico, Tlatelolco, and several other feudatory princes, were invited by Maxtlaton to an entertainment. The King of Mexico prudently excused himself, but the unsuspecting Tajatzin came to the place of entertainment, and was instantly put to death. The company were greatly alarmed, but nevertheless proclaimed Maxtlaton king, being in this, no doubt, much more influenced by fear than by affection. The King of Mexico escaped a sudden death by his absence at this time, only to perish in a manner more slow and ignominious. His revengeful foe Maxtlaton, not content with heaping insults upon him, decoyed his favourite wife into his hands, and sent her home dishonoured. Chimilpopoca was so much affected by this misfortune that he resolved to offer himself up as a sacrifice to his god; but before the resolution could be executed Maxtlaton sent a body of troops, who, entering Mexico without resistance, carried off the king alive. Chimilpopoca was imprisoned at Azcapozalco in a strong wooden cage, the common prison for criminals.

Itzcoatl raised to the throne of Mexico.

In the meantime the Mexicans raised to the throne Izcoatl, the son of Acamapitzin. His election was no less pleasing to Nezahualcojotl and his party than it was offensive to Maxtlaton. An alliance was quickly concluded between the exiled prince and the King of Mexico; and when the former commenced hostilities against the tyrant of Azcapozalco, the latter agreed to assist him. Maxtlaton accordingly prepared to wage war with the Mexicans. The Mexican populace, terrified at engaging so powerful an enemy, demanded that their king should submit and sue for a peace. But Montezuma, the brave son of Huitzilihuitl, persuaded them to agree to a commencement of hostilities. Conditions of peace, however, were first sent to Maxtlaton by the hands of Montezuma. They were rejected, and the Mexican ambassador forthwith went through the ceremony of declaring war. The Mexican populace were again thrown into the utmost consternation by the news that war was inevitable; and they now requested the king to allow them to retire from their city, of which they supposed the ruin to be certain. The king encouraged them with the hopes of victory. "But if we are conquered," replied they, "what will become of us?" "If that happen," answered the king, "we are that moment bound to deliver ourselves into your hands, to be made sacrifices at your pleasure." Prince Nezahualcojotl was forthwith summoned to repair to Mexico with his army. On the day after his arrival the allied forces encountered the Tepanecan troops under a general named Mazatl. After an obstinate and bloody contest, which lasted till night, the Tepanecan general fell by the sword of Montezuma, and his forces were driven into their capital city. On the following day their defeat was even more signal, and resulted in the capture of Azcapozalco. Maxtlaton attempted to hide himself, but being quickly discovered, he was beaten to death with sticks and stones. The city was plundered, the inhabitants were butchered, and the houses destroyed by the victors. This victory proved decisive in favour of the confederates. Every other place of strength in the country was quickly reduced, until the Tepanecans, finding themselves upon the verge of destruction, sent an humble embassy to the King of Mexico, requesting to be taken under his protection, and to become tributaries to him. Itzcoatl received them graciously, but threatened them with total extirpation if they violated the fidelity they had sworn to him.

Nezahualcojotl made king of Acolhuacan.

Itzcoatl, now finding himself firmly seated on the throne of Mexico, set about performing his engagements to the Acolhuacan prince. Nezahualcojotl was accordingly seated upon the throne of Acolhuacan. Having thus accomplished the conquest of Cojohuacan, a great part of the Tepanecan country, with the title of King of Tacuba, was given by Itzcoatl to Totoquihatzin, a grandson of Tezozomoc. An alliance was then formed between the Kings of Mexico, Acolhuacan, and Tepaneca. The conditions were, that they should assist each other in war, and should divide all plunder amongst themselves according to certain specified proportions. About this time the Xochimilcas, fearing lest the Mexicans should now turn their victorious arms against them, determined to commence hostilities against that rising state, before it should become more formidable by new conquests. Itzcoatl was no sooner informed of this determination, than he sent Montezuma with a great army against them. The Xochimilcas met him with one still more numerous; but being worse disciplined they were quickly defeated, and their city taken a short time afterwards.

Montezuma I., king of Mexico, A.D. 1436.

Izcoatl died in 1436, at a very advanced age, in the height of prosperity, and was succeeded by Montezuma I., the greatest monarch that ever sat on the Mexican throne. Scarcely had he been crowned when his aid was solicited by the Tezcucans against the Chalcese. The latter were almost annihilated in one desperate battle, and their city was levelled with the ground. Montezuma, on his return, found himself obliged to encounter an enemy more formidable, on account of his vicinity, than enemies more powerful at a distance. This was the King of Tlatelolco, who had formerly conspired against the life of Itzcoatl, and finding himself disappointed in this, had tried to reduce his power by entering into a confederacy with some of the neighbouring lords. At that time his designs proved abortive, but he resumed them in the time of Montezuma; the consequence was, that he was defeated and killed. One Moquihuix was chosen in his stead; and in the election of that chief it is probable that Montezuma had a considerable share. This was followed by conquests of a much more important nature. He added to his dominions the province of Cuihixcas, situated to the southward, and comprehending a tract of country more than 150 miles in breadth. Then, turning to the westward, he conquered another province named Tzompahuacan. This success, however, was for a short time interrupted by a war with Atonaltzin, lord of a territory in the country of the Mixtacas. Against this potentate Montezuma sent a considerable army, but had the mortification to be informed of its defeat. Chagrined at this first check, he determined to command his next army in person; but before he could call together another, Atonaltzin had formed a confederacy with the Huexotzincas and Tlascalans, who were glad of the opportunity, as they supposed, of reducing the power of the Mexicans. Their numbers, however, availed them but little; as Montezuma in the first engagement totally defeated the confederate army. By this victory the Mexican monarch became master not only of the dominions of Atonaltzin, but of those of many other neighbouring princes, against whom he had made war on account of their having put to death some Mexican merchants or couriers without any just cause. The conquest of Cuetlachtan or Cotasta, however, which he attempted in 1457, proved a much more difficult task. This province is situated on the coast of the Mexican Gulf, and had formerly been inhabited by the Olmecans, whom the Tlascalans had driven out. The inhabitants were very numerous; but dreading the power of Montezuma, called in to their assistance those of Tlascala, together with the Huexotzincas and the Cholulans. Montezuma sent against them an excellently equipped army, which, however, he did not on this occasion command in person. The Cotastese fought with great valour, but were unable to resist the royal forces; and their allies were almost totally destroyed. Six thousand two hundred of them were taken prisoners, and soon afterwards sacrificed to the Mexican god of war in the barbarous manner already described.

Mexican dominions changed, A.D. 1457.

Inundation and famine at Mexico, A.D. 1446.

During the reign of this great monarch a violent inundation happened in Mexico. The lake, swollen by the excessive rains which fell in 1446, poured its waters into the city with such violence, that many houses were destroyed, and the streets inundated to such a degree that boats were everywhere made use of. The inundation was soon followed by a famine. This was occasioned by the partial failure of the crop of maize in 1448, the ears whilst young and tender having been destroyed by frost. In 1450 the crop was totally lost for want of water; and in 1451, besides the unfavourable seasons, there was a scarcity of seed. Hence in 1452 the necessities of the people became so great, that they were actually obliged to sell themselves as slaves in order to procure subsistence. Montezuma opened the public granaries for the relief of the lower classes; but nothing could arrest the progress of the famine.

Axayacatl succeeds Montezuma.

Montezuma was succeeded by Axayacatl, who, like his predecessor, instantly commenced a war, for no other reason than that he might obtain prisoners to sacrifice at his coronation. He pursued Montezuma's plan of conquest, in which, however, he was not very successful; many of the provinces reduced by that monarch having revolted after his death, so that it was necessary to reconquer them. The Mexicans sustained an irreparable loss in 1469 and 1470 by the death of their allies the Kings of Tacuba and Acolhuacan. The King of Tacuba was succeeded by his son Chimilpopoca, and the Acolhuacan monarch by his son Nezahualpilli. A short time after the accession of the latter the war broke out between the Tlatelocos and Mexicans, which ended in the destruction of the former. Moquihuix, King of the Tlatclocos, had entered into an alliance with a great number of the neighbouring states, in order to reduce the Mexican power. He then prepared for war with many horrid ceremonies, of which the drinking of human blood was one. A day was appointed for attacking Mexico. At the set time the attack began and lasted until night, when the Tlatclolcos were obliged to retire. During the night Axayacatl disposed of his troops in all the roads which led to Tlatelolco, appointing them to meet in the market-place. The Tlatelolcos, finding themselves attacked upon all sides, retired gradually before the Mexicans, until at last they were forced into the market-place. During the tumult which ensued Moquihuix was killed, and his army was compelled to submit. The Tlatelolcos being thus reduced, Axayacatl next set out on an expedition against the Matlazincas, a tribe in the valley of Toluca, who still refused to submit to the Mexican yoke. Having proved successful in this expedition, he undertook to subdue Xiquipilco, a considerable city and state of the Otomies. Encountering the chief of that people in single combat, he was overmatched, and received a violent wound in the thigh. Notwithstanding this disaster, his army gained a complete victory, carrying off more than eleven thousand prisoners, amongst whom was the chief of the Otomies himself.

Tizoc and Ahuitzotl.

Axayacatl was succeeded by his elder brother, called Tizoc, who was shortly afterwards murdered in a conspiracy of his subjects. During the reign of Tizoc the Acolhuacans made war upon the Huexotzincas, ruined their city, and conquered their territory. Ahuitzotl, the brother of Tizoc, succeeded him in the kingdom of Mexico. His first object was to finish the great temple begun by his predecessor; and so great was the number of workmen employed that it was completed in four years. During the time it was building the king employed himself in making war with different nations, reserving all the prisoners he took for victims at the dedication of the temple. The number of prisoners sacrificed at this dedication in 1486 is said by Torquemada to have been 72,324, and by other historians is estimated at 64,060. In 1487 there happened a violent earthquake; and Chimilpopoca, King of Acolhuacan, having died, was succeeded by Totoquihuatzin II. Ahuitzotl died in the year 1502 of a disorder produced by a contusion in the head. At the time of his death the Mexican empire had reached its utmost extent.

Montezuma, A.D. 1502.

His successor, Montezuma Xocojotzin, or Montezuma the younger, was a person of great bravery, and was likewise a priest, and held in great estimation on account of the gravity and dignity of his deportment. But no sooner was the ceremony of his coronation terminated, than Montezuma began to discover a pride which nobody had before suspected. He deprived all the commoners of the offices they held about the court, declaring them incapable of holding any for the future. All the royal servants were now people of rank. Besides those who lived in the palace, six hundred feudatory lords and nobles came to pay court to him. In every respect he kept up, as far as was possible, an extravagant appearance of dignity, splendour, and luxury. But in no long time his prodigality rendered him very disagreeable to a great number of his subjects, though others were pleased with the readiness he showed to relieve the necessities of individuals, and his generosity in rewarding his generals and ministers. The reign of Montezuma, even before the arrival of the Spaniards, was far from being so glorious as those of his predecessors had been. He attempted to extort tribute from Tlascala, a small republic at no great distance from the capital; but the inhabitants had already inclosed all the lands of the republic with intrenchments, to which they now added a wall six miles in length on the west side, where an invasion was most to be apprehended. Behind these fortifications so well did they defend themselves, that though they were frequently attacked by the neighbouring states in alliance with Mexico, or subject to it, they were still able to maintain their ground. Montezuma's reign was also disturbed by disastrous losses and evil omens. In 1508 an expedition against a very distant region, named Amatla, completely failed. A great part of the soldiers perished under the inclemency of the weather, and the rest were killed in battle. By this and other calamities, together with the appearance of a comet, Montezuma was so terrified that he applied to the King of Alcohuacan, who was reported to be very skilful in divination. Nezahualpilli told him that the comet presaged the arrival of a new people; but this being unsatisfactory to the emperor, he conferred with a celebrated astrologer, who confirmed the interpretation of Nezahualpilli.

Conquest of Mexico undertaken by Cortez, A.D. 1518.

Mexico was first discovered by Hernandez de Cordova, who in 1517, in sailing towards the Bahamas, was driven by a succession of severe storms on the coast of Yucatan. On the 10th of February 1519 Hernando Cortez set sail for the conquest of Mexico from the Havannah, and, after touching at Yucatan, arrived in Passion-week of the same year at the harbour of St Juan de Ulua. Here he was met by two Mexican canoes, which carried two ambassadors from the emperor of that country, and showed the greatest signs of peace and amity. Their language was translated into the Yucatan tongue by a female prisoner, whom they had recently captured; after which a Spaniard named Jerom de Aguilar interpreted the meaning in Spanish. This slave was afterwards named Donna Marina, and proved very useful in their conferences with the natives. By means of his two interpreters, Cortez learned that the other part of the embassy was to inquire what his intentions were in visiting these coasts. He accordingly informed the ambassadors that he came to propose matters of the utmost consequence to the welfare of the prince and his kingdom. Next morning, without waiting for any answer, he landed his troops, horses, and artillery, and began to erect huts for his men, and to fortify his camp. The day following the ambassadors had a formal audience, at which Cortez acquainted them that he came from Don Carlos of Austria, king of Castile, the greatest monarch of the East, and was intrusted with propositions of such moment that he would impart them to none but the emperor himself, and therefore required to be conducted immediately to the capital. This demand produced the greatest uneasiness, and the ambassadors did all in their power to dissuade Cortez from his design, endeavouring to conciliate his good will by the presents sent him by Montezuma. But Cortez insisted on being admitted to a personal interview with their sovereign. During this conversation some painters in the retinue of the Mexican chiefs had been diligently employed in delineating, upon white cotton cloths, figures of the ships, horses, artillery, soldiers, and whatever else attracted their eyes as singular. These sketches were then despatched to Montezuma by trained couriers posted at proper stations along the road. In a few days messengers arrived from the royal residence with many rich presents to Cortez, but at the same time with the intelligence that Montezuma would not give his consent that foreign troops should approach nearer to his capital, or even allow them to continue longer in his dominions.

Montezuma commands Cortez to leave his dominions, A.D. 1519.

In a short time a deputy named Teutile arrived with another present from Montezuma, and together with it delivered the ultimate orders of that monarch to depart instantly out of his dominions; and when Cortez, instead of complying with his demands, renewed his request of audience, the Mexican immediately left the camp with strong marks of surprise and resentment. Next morning none of the natives appeared; all friendly correspondence seemed to be at an end, and hostilities were expected to commence every moment. Cortez, without allowing his men time for reflection, immediately set about carrying his designs into execution. In order to give a beginning to a colony, he assembled the principal persons in his army, and by their suffrages elected a council and magistrates, in whom the government was to be vested. The new settlement received the name of Villa Rica de la Vera Cruz, that is, "the rich town of the true cross."

The government of the new colony vested in Cortez.

Before this court of his own making, Cortez did not hesitate to resign all his authority, and was immediately re-elected chief-justice of the colony, and captain-general of his army, with an ample commission, in the king's name, to continue in force till the royal pleasure should be further known. The soldiers eagerly ratified their choice by loud acclamations; and Cortez, now considering himself as no longer accountable to any subject, began to assume a much greater degree of dignity, and to exercise more extensive powers than he had hitherto done. Having strengthened himself still further by an alliance with one of Montezuma's own tributaries, the petty prince of Cempoalla, he resolved to advance into the country.

Yet, as he had thrown off all dependence on Velasquez, the governor of Cuba, who was his lawful superior, he was apprehensive of his interest at court, and thought proper, before he set out on his intended expedition, to take the most effectual measures against the impending danger. With this view, he persuaded the magistrates of his colony to address a letter to the king, containing a pompous account of their own services, of the country they had discovered, and of the motives which had induced them to throw off their allegiance to the governor of Cuba, and to settle a colony dependent on the crown alone, in which the supreme power, civil as well as military, had been vested in Cortez; humbly requesting their sovereign to ratify what had been done under his royal authority. Some soldiers and sailors, however, secretly disaffected to Cortez, formed a design of seizing one of the brigantines, and making their escape to Cuba, in order to give such intelligence to the governor as might enable him to intercept the vessel which was to carry the treasure and despatches to Spain. But before this conspiracy was ready for execution, the secret was discovered by one of the associates. To prevent such plots in future, Cortez, without any hesitation, burned his fleet, and thus rendered it necessary for his troops to follow wherever he chose to lead. He then began his march into the interior, with 500 infantry, 15 horse, and 6 field-pieces; and with a reinforcement furnished by the Prince of Cempoalla, consisting of 400 regular troops and 200 of those Indians called Tamanes, whose office was to carry burdens and perform all manner of servile labour.

Conspiracy.

Cortez engages in war with the republic of Tlascala.

Nothing memorable happened till the Spaniards arrived on the confines of the republic of Tlascala. As the inhabitants of that province were implacable enemies of Montezuma, Cortez hoped that it would be an easy matter for him to procure their friendship; but his ambassadors were detained, a circumstance which led him to infer that the Tlascalans were hostile. He accordingly approached the city, and soon found that his small force was surrounded by an army of 50,000 men. In the battle which ensued the discipline and equipments of the Europeans overcame this immense host. The loss of three other battles effectually subdued the valour of the natives, and at last peace was concluded to the great satisfaction of both parties. The Tlascalans yielded themselves as vassals to the crown of Castile, and engaged to assist Cortez in all his operations, in return for the protection which he guaranteed to extend to their republic.

Cortez prosecutes his enterprise.

As soon as his troops were fit for service, Cortez resolved to continue his march towards Mexico, notwithstanding the remonstrances of the Tlascalans, who looked upon his destruction as inevitable if he put himself into the power of such a faithless prince as Montezuma. But the emperor had informed Cortez that he agreed to receive his visit, and that he had given orders for his friendly reception at Cholula, the next place of any consequence on the road to Mexico. Cortez was received with much seeming cordiality; but 6000 Tlascalan troops who accompanied him were obliged to remain without the town, as the Cholulans refused to admit their ancient enemies within their precincts. In a short time Donna Marina, the interpreter, received information from an Indian woman of distinction, whose confidence she had gained, that the destruction of the Spaniards was concerted; that a body of Mexican troops lay concealed near the town; that some of the streets were barricaded, whilst in others deep pits or trenches were dug, and slightly covered over, as traps into which the horse might fall; that stones and missile weapons were collected upon the tops of the temples; and that the fatal hour was already at hand. Cortez, alarmed at this news, resolved to anticipate his enemies. On a signal given, his troops rushed out and attacked the multitude in front, the Tlascalans at the same time assailing them in the rear; the streets were filled with slaughter, and the temples, which afforded a retreat to the priests and some leading men, were set on fire, in consequence of which they perished in the flames. At length the carnage ceased, after the slaughter of 6000 Cholulans, without the loss of a single Spaniard.

From Cholula Cortez continued his march to Mexico with great circumspection and the strictest discipline, though without seeming to suspect the prince whom he was about to visit.

Meeting of Cortez and Montezuma.

When the Spaniards drew near the city, about 1000 persons of distinction came forth to meet them, and announce the approach of the emperor himself. Preceded by all the pomp and pageantry of an oriental monarch, Montezuma appeared in a chair or litter richly ornamented with gold and feathers of various colours, surmounted by a canopy of curious workmanship. When he drew near, Cortez, dismounting, accosted him with profound reverence, after the European fashion. He returned the salutation, according to the mode of his country, by touching the earth with his hand, and then kissing it. Nothing material passed at this first interview. Montezuma conducted Cortez to the quarters which had been prepared for his reception, and immediately took leave of him with a politeness not unworthy of a more refined court. The first care of Cortez was to take precautions for his security, by planting the artillery so as to command the different avenues which led to his quarters, and by appointing a large division of his troops to be always on guard. The three subsequent days were employed in viewing the city, the appearance of which, so far superior in the order of its buildings and the number of its inhabitants to any place the Spaniards had beheld in America, and yet so little resembling the structure of a European city, filled them with surprise and admiration.

The city of Mexico.

The access to the city of Mexico or Tenochtitlan was by artificial causeways or streets, formed of stones and earth, about 30 feet in breadth. As the waters of the lake during the rainy season overflowed the level country, these causeways were of considerable length; that of Tacuba, on the W., being a mile and a half; that of Tezcuco, on the N.W., 3 miles; and that of Cuoyacan, towards the S., 6 miles. On the E. there was no causeway, and the city could be approached only by canoes. As the approaches to the city were singular, so its construction was remarkable. Not only the temples of their gods, but the houses belonging to the monarch and to persons of distinction, were of such dimensions that, in comparison with any other buildings which had been discovered in America, they might even be termed magnificent. The habitations of the common people were mean, resembling the huts of other Indians; but they were all placed in a regular manner on the banks of the canals, which passed through the city in some of its districts, or on the sides of the streets which intersected it in other quarters. In this city, the pride of the New World, and the noblest monument of the industry and the art of man whilst unacquainted with the use of iron, the Spaniards reckon that there were at least 60,000 inhabitants.

Cortez resolves to seize Montezuma in his palace.

As soon as Cortez had entered Mexico, he had become sensible that, from an excess of confidence in the superior valour and discipline of his troops, he had pushed forward into a situation where it was difficult to continue, and from which it was dangerous to retire. At the same time he knew that the countenance of his own sovereign was to be obtained only by a series of victories. He therefore fixed upon a plan no less extraordinary than daring. He determined to seize Montezuma in his palace, and to carry him as a prisoner to the Spanish quarters. At his usual hour of visiting Montezuma, Cortez went to the palace accompanied by Alvarado, Sandoval, Lugo, Velasquez de Leon, and Davila, five of his principal officers, and with as many trusty soldiers. Thirty chosen men followed, not in regular order, but sauntering at some distance, as if they had no object but curiosity; small parties were posted at proper intervals in all the streets leading from the Spanish quarters to the court; and the remainder of his troops, with the Tlascalan allies, were under arms, ready to sally out upon the first alarm. Cortez and his attendants were admitted without suspicion; the Mexicans retiring, as usual, out of respect. He addressed the monarch in a tone very different from that which he had employed in former conferences, reproaching him bitterly as the author of a violent assault made upon the Spaniards at Cempoalla by one of his officers. Montezuma, confounded at this unexpected accusation, asserted his own innocence with great earnestness; and, as a proof of it, gave orders instantly to bring the culprit to Mexico. Cortez replied that a declaration so respectable left no doubt remaining in his own mind; but that his followers would never be convinced that Montezuma did not harbour hostile intentions against them, unless he removed from his own palace and took up his residence in the Spanish quarters. The first mention of so strange a proposal deprived Montezuma of speech, and almost of motion. At length he haughtily answered, that persons of his rank were not accustomed to give themselves up voluntarily as prisoners. At length, after he had been alternately coaxed and intimidated for the space of three hours, he complied with their request, and was carried off in silent pomp to the Spanish quarters.

Cortez rules the empire, A.D. 1520.

In a short time Cortez had entirely gained the ascendant over the unhappy monarch; and he took care to improve his opportunity to the utmost. He sent his emissaries into different parts of the kingdom, accompanied with Mexicans of distinction, who might serve them both as guides and protectors. He urged Montezuma to acknowledge himself a vassal of the crown of Castile; to hold his crown of him as superior; and to subject his dominions to the payment of an annual tribute. With this requisition, humiliating as it was, Montezuma complied. He then, at the request of Cortez, accompanied this profession of fealty with a magnificent present to his new sovereign; and, after his example, his subjects brought in very liberal contributions. Yet, although often importuned, he obstinately refused to change his religion, or abolish the superstitious rites which had been for so long a time practised throughout his dominions. In an ebullition of zeal, Cortez led out his soldiers in order to throw down by force the idols in the great temple; but the priests taking arms in defence of their altars, and the people crowding with great ardour to support them, the prudence of Cortez overruled his zeal, and induced him to desist from his rash attempt, after dislodging the idols from one of the shrines and placing in their stead an image of the Virgin Mary. Scarcely had he escaped from this danger when he was startled by the news that an armament sent by Velasquez, the governor of Cuba, had arrived at Vera Cruz. He afterwards learned that it consisted of 18 ships and 900 men, under a brave officer named Pamphilo de Narvaez, and that their instructions were, to seize Cortez and his principal officers, to send them prisoners to Velasquez, and then to complete the discovery and conquest of the country in his name.

The armament sent from Cuba against Cortez defeated.

After attempting in vain to induce Narvaez to share with him the glory and gain of subduing the country, Cortez resolved to trust his fate to the issue of a war. He therefore left 150 men under the command of Pedro de Alvarado, to guard the capital and the captive emperor; and marched with the remainder to meet his formidable opponent, who had taken possession of Cempoalla. Even af-being reinforced by Sandoval, the governor of Vera Cruz, the force of Cortez did not exceed two hundred and fifty men. He hoped for success chiefly from the rapidity of his movements and the possibility of surprising his enemies; and as he chiefly dreaded their cavalry, he armed his soldiers with long spears, accustoming them to that deep, compact, and solid order in which the use of these weapons becomes most formidable. At last he attacked Narvaez in the night-time, and having entirely defeated and taken him prisoner, obliged all his troops to own allegiance to himself.

Dangerous situation of the Spaniards left at Mexico.

A short time after the defeat of Narvaez a courier arrived from Mexico with the disagreeable intelligence that the Mexicans had taken arms, and having seized and destroyed the two brigantines which he had built in order to secure the command of the lake, had attacked the Spaniards in their quarters, and had carried on hostilities with such fury that Alvarado and his men must either have been cut off by famine or overpowered by the multitude of their enemies. This revolt had been excited by motives which rendered it still more alarming. On the departure of Cortez for Cempoalla, the Mexicans had held a consultation for restoring their sovereign to liberty, and driving out the Spaniards. The Spaniards in the city suspected and dreaded these machinations; but Alvarado, instead of attempting to soothe or cajole the Mexicans, waited the return of one of their solemn festivals, fell upon them, unarmed and unsuspicious of danger, and massacred six hundred in cold blood. An action so cruel and so treacherous, filled not only the city, but the whole empire, with rage and indignation.

Cortez returns to Mexico, but is attacked by the natives.

Cortez advanced with the utmost celerity to the relief of his distressed companions, and entered the capital without opposition. But by this time indignation and success had so intoxicated him that he refused, with strong words of contempt, a personal interview with Montezuma. His expressions being reported amongst the Mexicans, they suddenly flew to arms, and made such a violent and sudden attack, that all the valour and skill of Cortez were scarcely sufficient to repel them. After exerting his utmost efforts for a whole day, he was obliged to retire with the loss of twelve killed and upwards of sixty wounded. When the Mexicans approached the next morning to renew the assault, Montezuma, who was still at the mercy of the Spaniards, advanced to the battlements in his royal robes, and addressed his subjects in favour of the Spaniards. But they testified their resentment with loud murmurings, and at length broke forth with such fury that they wounded him with two arrows, and struck him to the ground with a stone. The unhappy monarch now obstinately refused all nourishment, and in a short time ended his days. Upon the death of Montezuma, Cortez having lost all hope of bringing the Mexicans to any terms of peace, prepared for retreat. But his antagonists having taken possession of a high tower in the great temple, which overlooked the Spanish quarters, and placed there a garrison of their principal warriors, the Spaniards were so much exposed to their missile weapons, that none of them could stir without imminent danger. In an attempt to capture this post Juan de Escobar, with a large detachment of chosen soldiers, was thrice repulsed. Cortez then caused a buckler to be tied to his arm, as he could not manage it from a wound which he had received in the hand, and rushed with his drawn sword amongst the thickest of the combatants. Encouraged by the presence of their general, the Spaniards returned to the charge with such vigour that they gradually forced their way up the steps, and drove the Mexicans to the platform at the top of the tower. There a desperate hand-to-hand struggle raged for three hours, when all the Mexicans were either slain or hurled from the battlements. As soon as the Spaniards became masters of the tower, they set fire to it, and, without further molestation, continued the preparations for their retreat.

Retreat of Cortez.

Towards midnight, they began their march in three divisions. But they had not proceeded far before they were suddenly alarmed with the sound of warlike instruments, and found themselves assaulted on all sides by an innumerable multitude of their enemies. The Spaniards advanced with precipitation. At last, overborne with the numbers of the enemy, they began to give way, and in a moment the confusion was universal. More than four hundred Spanish soldiers perished, together with many officers of distinction. All the artillery, ammunition, and baggage were lost; the greater part of the horses, and above two thousands Tlascalans were killed, and only a very small part of their treasure was saved. The first care of the Spanish general, after he had succeeded in escaping from the city, was to find some shelter for his small shattered army. At last he discovered a temple seated on an eminence, in which he found not only the shelter he wanted, but also some provisions. For six days afterwards the Spaniards continued their march through a barren, ill-cultivated, and thinly-peopled country, where they were often obliged to feed on berries, roots, and the stalks of green maize; at the same time they were harrassed without intermission by large parties of Mexicans, who attacked them on all sides. On the sixth day they reached Otumba, not far from the road between Mexico and Tlascala. Early next morning, when they reached the summit of an eminence before them, a spacious valley opened to their view, covered with a vast army of Mexicans as far as the eye could reach. At the sight of this incredible multitude the Spaniards were astonished, and even the boldest amongst them began to despair. But Cortez, without allowing time for the slightest hesitation, led them instantly to the charge. With little difficulty the small compact band pierced and shattered the mighty mass of their foes; but the broken battalions, after each successive repulse, re-formed and returned to the conflict, until the Spaniards were ready to sink under their repeated efforts, without seeing any end to their toil, or any hope of victory. At this crisis Cortez, along with four desperate cavaliers, cut his way through the chosen body of nobles that guarded the standard of the empire, bore down the Mexican general with his lance, and snatched the imperial ensign. The moment that their leader fell, and the standard, towards which all directed their eyes, had disappeared, a universal panic struck the Mexicans; every ensign was lowered, and each soldier, throwing away his weapons, fled with precipitation to the mountains.

Measures adopted by Cortez.

The day after this important action, which was fought on the 8th of July 1520, the Spaniards entered the Tlascalan territories, where they were received with the most cordial friendship. Cortez now set himself assiduously to prepare for a second invasion of Mexico. He drew a small supply of ammunition, and two or three field-pieces, from his stores at Vera Cruz. He despatched an officer with four ships of Narvaez's fleet to Hispaniola and Jamaica, to engage adventurers, and to purchase horses, gunpowder, and other military stores; and as he knew that it would be in vain to attempt the reduction of Mexico unless he could secure the command of the lake, he gave orders to prepare, in the mountains of Tlascala, materials for building twelve brigantines, so that they might be carried to the water in pieces, ready to be put together and launched when he stood in need of their service. Without giving his soldiers an opportunity of caballing, he daily led them against the people of the neighbouring provinces, who had cut off some detachments of Spaniards during his misfortunes at Mexico; and as he was constantly attended with success, his men soon resumed their wonted sense of superiority. About this period an armament fitted out by Francisco de Garay, governor of Jamaica, who had long aimed at dividing with Cortez the glory and the gain of annexing the empire of Mexico to the crown of Castile, arrived at Vera Cruz, and were soon persuaded to throw off their allegiance to their master, and to enlist with Cortez. About the same time a ship arrived from Spain, freighted by some private adventurers, with military stores; and the cargo was eagerly purchased by Cortez, whilst the crew, following the example of the rest, joined him at Tlascala. From these various quarters the army of Cortez was reinforced with one hundred and eighty men and twenty horses, by which means he was enabled to dismiss such of the soldiers of Narvaez as were most troublesome and discontented; after the departure of whom he still mustered upwards of five hundred infantry, of whom eighty were armed with muskets or cross-bows, forty horsemen, and nine pieces of artillery. At the head of these, with ten thousand Tlascalans and other friendly Indians, he began his march towards Mexico on the 28th of December, six months after his fatal retreat from that city.

Second advance on Mexico.

As soon as Cortez entered the enemy's territories, he discovered various preparations to obstruct his progress. But his troops forced their way with little difficulty, and took possession of Tezcuco, the second city of the empire, situated upon the banks of the lake, about 20 miles from Mexico. For three months part of his troops were engaged in building brigantines, and the other part in reducing the towns situated round the lake. Meanwhile several of the cities tributary to Mexico were induced, through hatred to their oppressors, to make common cause with the invaders, and not only to acknowledge the King of Castile as their sovereign, but to supply the Spanish camp with provisions, and to strengthen his army with auxiliary troops. At length intelligence arrived that the materials for building the brigantines were completely finished, and waited only for a body of Spaniards to conduct them to Tezcuco. The command of this convoy, consisting of two hundred foot soldiers, fifteen horsemen, and two field-pieces, was given to Sandoval. This brave soldier proved worthy of the confidence reposed in him, and conducted his charge safely to Tezcuco.

Mexico besieged, A.D. 1521.

Cortez determined to attack the city from three different quarters; from Tezcuco on the E. side of the lake, from Tacuba on the W., and from Cuayocan towards the S. These towns were situated on the principal causeways which led to the capital, and were intended for their defence. He appointed Sandoval to command in the first, Pedro de Alvarado in the second, and Christoval de Olid in the third. He formed the brigantines into three divisions, allotting one to each station, with orders to second the operations of the officer who commanded there. From all the three stations he pushed on the attack against the city with equal vigour, but in a manner very different from that in which sieges are conducted in regular war. Each morning his troops assaulted the barricades which the enemy had erected on the causeways, forced their way over the trenches which they had dug, and penetrated into the heart of the city, in hopes of obtaining some decisive advantage; but when the obstinate valour of the Mexicans had rendered the efforts of the day ineffectual, the Spaniards retired in the evening to their former quarters. After this plan of attack had been followed for a month without any success, Cortez resolved to give it one trial more, and if unsuccessful, to relinquish it altogether. With this view he sent instructions to Alvarado and Sandoval to advance with their divisions to a general assault, and took the command in person of that which was posted on the causeway of Cuayocan. Animated by his presence and the expectation of some decisive event, the Spaniards pushed forward with irresistible impetuosity; broke through one barricade after another; forced their way over the ditches and canals, and having entered the city, gained ground incessantly, in spite of the multitude and ferocity of their opponents. But Guatimozin commanded the troops posted in the front, to slacken their efforts, in order to allure the Spaniards to push forward. On a signal given by him, the priests in the great temple struck the great drum consecrated to the god of war; and no sooner did the Mexicans hear its solemn sound than they rushed upon the enemy with frantic rage. The Spaniards, unable to resist the fury of the onset by men maddened by religious zeal, began to retire, at first leisurely and in order, but as the enemy pressed on, and their own impatience to escape increased, the terror and confusion became general. Cortez himself would have been carried away captive by six Mexican captains, had not two of his officers sacrificed their own lives to save him. Above sixty Spaniards perished in the rout; and what rendered the disaster more afflicting, forty of these fell alive into the hands of the enemy, and were doomed to have their quivering hearts torn from their bosoms and offered up with barbarous rites to hideous idols. But the Mexicans did not rely on the efforts of their own arms alone. They sent the heads of the Spaniards whom they had sacrificed to the leading men in the adjacent provinces, and assured them that the god of war had declared that in eight days these hated enemies should be finally destroyed. This prediction gained universal credit amongst a people prone to superstition. The Indian auxiliaries of Cortez abandoned the Spaniards as a race of men devoted to destruction, and the Spanish troops were left almost alone in their stations. Cortez, however, resolved to falsify the prophecy; and accordingly suspended all military operations during the period marked out by the oracle. The fatal term thus expired without any disaster. His allies, ashamed of their own credulity, now returned to their station. Other tribes joined his standard; and such was the changeableness of a simple people, moved by every slight impression, that in a short time Cortez saw himself, if we may believe his own account, at the head of 150,000 Indians.

The capture of Mexico.

Even with such a numerous army he found it necessary to adopt a new and more cautious system of operations. He made his advances slowly and cautiously, levelling the houses and filling up the canals as he advanced, and gradually contracting the retreat of the enemy. At length all the three divisions penetrated into the great square in the centre of the city, and made a secure lodgment there. Three-fourths of the city were now reduced and laid in ruins; and the remaining quarter was wasting fast before the attacks of famine and pestilence. At this crisis the brave Guatimozin resolved to proceed in person to rouse the distant provinces of the empire to arms. With this intent he embarked in a canoe, and was speeding swiftly over the lake when he was captured by a brigantine, and delivered into the hands of Cortez. As soon as the fate of their sovereign was known, the resistance of the Mexicans ceased, and Cortez took possession of that small part of the capital which yet remained undestroyed. Thus terminated, after it had continued for seventy-five days, the siege of Mexico, the most memorable event in the conquest of America. The exultation of the Spaniards was quickly damped by the disappointment of those hopes which had animated them amidst so many hardships and dangers. Instead of the inexhaustible wealth which they expected, their rapacity could collect only an inconsiderable booty amidst ruins and desolation. Guatimozin, aware of his impending fate, had ordered what remained of the riches amassed by his ancestors to be thrown into the lake. The Spaniards, thus deprived of their expected reward, fell into a state of uncontrollable discontent. Some accused Cortez and his confidants of having secretly appropriated to their own use a large portion of the riches which should have been brought into the common stock. Others blamed Guatimozin for obstinacy in refusing to discover the place where he had hidden his treasure. To quiet this universal

Guatimozin tortured.

murmur, Cortez was driven to subject Guatimozin to torture, in order to force from him a discovery of the royal treasures, which it was supposed he had concealed. The unfortunate monarch bore the most refined cruelty with the invincible fortitude of an American warrior, until Cortez, ashamed of a scene so horrid, rescued him from the hands of his torturers.

The Spaniards become masters of the Mexican empire.

The fate of the capital, as both parties had foreseen, decided that of the empire. The provinces one after another submitted to the conquerors. Small detachments of Spaniards, marching through them without interruption, penetrated in different quarters to the great Southern Ocean, which, according to the ideas of Columbus, they imagined would open a short and easy passage to the East Indies, and thus secure to the crown of Castile all the envied wealth of those fertile regions; and the active mind of Cortez began already to form plans for attempting this important discovery. In his subsequent schemes, however, he was disappointed; but from this time until the revolutionary spirit broke out in the New World, not long after the commencement of the present century, Mexico remained in the hands of the Spaniards.

II.—HISTORY OF MEXICO FROM THE COMMENCEMENT OF THE REVOLUTION TO THE PRESENT TIME.

For nearly three centuries after the conquest of Cortez, Mexico remained quietly subject to the Spanish yoke; but the internal tranquillity thus enjoyed ceased with the invasion of Old Spain by the armies of Napoleon. But before proceeding to narrate the events which have terminated in the separation of Mexico from the mother country, it will be necessary briefly to review the system of colonial policy by which it was so long governed, and to point out the causes which ultimately led to the assertion of independence. It is to the complication of abuses, to which the old system gave rise, that we must mainly attribute those events which have changed the destiny of the New World.

Government of Spanish Mexico.

The Spanish viceroy in Mexico was endowed with the prerogatives of royalty. He was commander-in-chief of the troops, and he regulated the military operations, and filled up all vacancies. All sentences of every description bore his signature, nor was there any appeal from his decision. The only checks which interposed between him and despotic sovereignty were the *residencia*, or legal investigation of his conduct, to which the king might subject him on his return to Spain, a measure which was seldom or never enforced; and the *Audiencia*, or the court of appeal in the last resort. This body possessed considerable power and influence. It had control over all other tribunals, ecclesiastical as well as civil, in every case where the value of the subject in litigation did not exceed ten thousand dollars. It likewise enjoyed the privilege of corresponding directly with the sovereign and with the Council of the Indies, a board at which the king was supposed constantly to preside in person, and whose sanction it was necessary to obtain before orders, decrees, or projects of reform, although emanating from the crown, could acquire the force of law. This privilege might have rendered this body an efficient check upon the conduct of the viceroy if the latter had not possessed such inordinate power. He was himself honorary president of the body, and had thus every opportunity of conciliating the members, and attaching them to his interests and those of the Europeans. They were more easily swayed in this direction, as they were always exclusively natives of old Spain.

Municipal corporations.

Besides the boards already noticed, the municipal corporations, called sometimes the *Cabildo*, sometimes the *Ayuntamiento*, and sometimes the *City*, had a considerable share of influence. Their members, called *regidors*, their president, the *corregidor*, and their executive officers, the *syndics*, were chosen from the people, and originally by the people. But in a short time the situations of alcalde and regidor were disposed of to the highest bidder, the purchaser having the power of relinquishing them in favour of relatives or friends. These functionaries, however, uniformly proved the friends of the Creoles; for they were connected with them by numerous ties, and by a community of interest.

State of the laws.

The *Recopilacion de las Leyes de las Indias*, or general collection of the laws of the Indies, was the name given to that chaotic mass of contradictory statutes by which the decisions of the tribunals were supposed to be determined. These statutes were originally merely decrees upon different subjects, emanating from the king or from the Council of the Indies. But it was not long before many of these decrees were annulled by others subsequently issued, so that it was scarcely possible to know which statutes were in force, and which had fallen into disuse or been suspended. An appeal to judicial authority had thus in it all the uncertainty and hazard of a game of chance; and this was further increased by different professions and corporate bodies enjoying various special privileges or *fueros*. Each of these exempted the persons who chose to plead it from the jurisdiction of the ordinary authorities, and made them amenable in all civil and criminal causes to the tribunal of the head of the body to which they belonged. It thus happened that the native American was generally the sufferer in cases in which his opponent was a European; for the difficulty of obtaining redress in any dispute was augmented by the circumstance of the latter enjoying a double or triple *fuero*, as a merchant, a government officer, a dignitary of the church, or at least as holding some rank in the militia.

Ecclesiastical establishments.

To complete the outline of that mighty fabric by which the authority of Spain in the New World was so long supported, it is necessary briefly to advert to ecclesiastical establishments. These were altogether independent of the see of Rome, and the pope could neither fulminate bulls nor hold any sort of intercourse with Spanish America, unless through the medium of the court of Madrid and the Council of the Indies. As might have been expected under such circumstances, a traffic in bulls became an important branch of the royal revenue. The king bought of the Holy See indulgences and dispensations of all kinds, and retailed them to his American subjects at an enormous profit. The business was managed with as much strictness and regularity as an ordinary commercial transaction, the monopoly of tobacco, for example; and so jealous was the king of his right, that the most severe penalties were not only enacted, but enforced against ecclesiastics who dared to infringe the regulations.

Evils of the Spanish colonial system.

Such is the general view of the colonial system of Spain; and when we consider that all the great offices of state, not excepting the viceregal dignity itself, were open alike to Americans and Europeans, every subject of the crown being eligible, its defects, in theory at least, are scarcely so glaring as they are sometimes represented. The evils, many and grievous, consisted in the practice and in the maintenance of a system of laws by which the colonies were sacrificed to the mother country. Every situation, from the highest to the lowest, was bestowed upon Europeans. Indeed, the colonial offices were disposed of in Madrid to the highest bidder; and at one time the proceeds, like the traffic in bulls, formed a not inconsiderable item of the royal revenues. Of the fifty viceroys who governed Mexico from 1535 to 1808, only one was an American, and even he was born in Peru. But as the exclusive enjoyment of these privileges could only be preserved to the Spaniards by the ignorance of the natives, almost every species of learning was not only discouraged, but prohibited, and pains and penalties were annexed to the infringement of the laws relating to it. The Latin grammar, the philosophy of the schools, and civil and ecclesiastical jurisprudence, were the only subjects which the Inquisition allowed to be taught. No book could circulate among the people until it had been thoroughly tested and sanctioned by the monks. But whilst ignorance was ranked amongst the virtues, some branches of industry were degraded into crimes. The Americans were prohibited, under severe penalties, from raising flax, hemp, or saffron, and growing tobacco was a government monopoly. The cultivation of the olive, the mulberry, and the vine, was also frustrated by the same blind policy; and even the growth of the more precious articles of what we term colonial produce, such as cacao, coffee, and indigo, was only tolerated under certain limitations, and in such quantities as the mother country might require annually to import. The colonists were also forbidden to manufacture anything which could be supplied by the mother country. Even foreign trade was for a long time prohibited on pain of death. At the same time licenses were granted for the introduction of any article of foreign produce during a limited period. For these enormous sums were paid by the leading commercial houses; and a share in the profits accruing from the speculation commenced with the viceroy, and extended to the meanest offices. But the exclusion of foreign vessels from the Mexican ports was not all that the rapacity of Spain laid claim to. Even ships in distress were by a royal ordinance ordered to be seized as prizes, and their crews thrown into prison. Nothwithstanding all the efforts of Spain, the exclusion of foreign vessels from her colonies gave rise to one of the most extraordinary systems of organized smuggling which the world ever witnessed. This was known under the name of the contraband or forced trade, and was carried on in armed vessels which often bade defiance to the coast blockades of Spain, and, fighting their way to the American ports, landed great quantities of European goods.

Other evils of the Spanish colonial system.

Such was the colonial system of Spain, which on all hands is admitted to have been worse even than that of the Portuguese or of the Dutch; and such were the evils to which it gave rise. When, therefore, in connection with these evils we further consider that the civil, fiscal, and criminal administration was tyrannical, unjust, or partial; that exactions in the shape of taxes, duties, and tithes, were levied with unexampled severity; that amongst the taxes was one which has justly been called "the horrible *alcavala*," and pressed heavily on all classes, being levied *in infinitum* on every transfer of goods; that nothing escaped tithes, and that every individual was compelled to purchase annually a certain number of the papal bulls, under a penalty of forfeiting various important advantages; that every stage of legal procedure was in the most corrupt and deplorable state, and that the administration of justice had scarcely any existence whatever; that imprisonment was the grand recipe for every malady; that in the most horrible dungeons ill diet, filth, infectious diseases, and corporal punishment, including occasional torture, all combined to unhumanize the fettered victim; and, finally, that the Inquisition bound in chains of darkness the minds of all classes of the community from the viceroy downwards;—he would be a bold theorist who should venture to affirm that Spain did not deserve that fate which eventually befel her possessions in the New World.

Events in Spain; their effect in America, A.D. 1808-1810.

How long an indisposition upon the part of the Creoles to assert their rights might have continued, had not the events of the year 1808 occurred, it is impossible to say; but it is generally admitted that the insurrection of Aranjuez, which led to the dismissal of Godoy, Prince of the Peace, and to the abdication of Charles VI., gave the first shock to the royal authority in America. Authentic intelligence of the resignation of the Spanish monarch arrived in Mexico on the 15th of July 1808. The inhabitants were thrown into a ferment of indignation. Crowds eagerly assembled in the squares and public walks, and threats of vengeance against France were mingled with strong expressions of adherence to the cause of the deposed monarch. The municipality and the popular party demanded the immediate creation of a *junta* in imitation of the mother country, composed of representatives of the different corporations of the kingdom. The Audiencia were adverse to such a course; and finding that the viceroy, Don Jose Iturrigaray, was inclined to favour their opponents, they contrived to arrest him and throw him into prison. For the time their plans proved completely successful. Iturrigaray, after remaining a short time in the dungeons of the Inquisition, was conveyed to Vera Cruz, and sent a prisoner to Cadiz charged with a design to establish himself upon an independent throne, and with having acted independently of the authority of the central junta. Not a few influential members of the Cabildo, who had voted for a Mexican junta, were arrested and either banished or otherwise disposed of. The viceregal authority was for the time confided to the Archbishop Lizana. In 1809, however, the archbishop was replaced by the Audiencia, to whom the central junta transferred the reins of government. The violent and contemptuous conduct of this body only served to bring matters more speedily to a crisis. A general feeling of hostility towards the Spaniards spread throughout the country, and on the morning of the 16th September 1810 the standard of revolt and independence was publicly unfurled by Don Miguel Hidalgo y Costilla, curate of the village of Dolores, in the province of Guanajuato. Seven Europeans, resident in Dolores, became the first victims of the revolutionary movement. They were thrown into prison, and their property seized and distributed amongst Hidalgo's followers. The news of this first exploit spread throughout the country with the rapidity of lightning, and was everywhere hailed as a propitious omen. His force increased so suddenly, that on the 18th he found himself in possession of two towns, each containing 16,000 inhabitants, in both of which places the confiscated property of the Europeans enabled him to reward his partizans as well as to add to their numbers.

Capture of Guanajuato, A.D. 1810.

His next object was Guanajuato, the capital of the province, and also the emporium of the Spanish treasures in that part of the country. Little opposition was offered to the entrance of his troops, who were immediately joined by the whole population of the town, and carried all before them. The town was given up to pillage; the Europeans were butchered without mercy; their property was eagerly seized; and before next morning there was not left standing a single house which had belonged to a Spaniard. An enormous quantity of money, estimated at five millions of dollars, was found in the alhondiga or granary, to which the inhabitants had transported their most valuable effects. During his stay at Guanajuato, Hidalgo established a sort of government, a mint with all the appurtenances for coining money, and a foundry for casting cannon.

Proceedings of the new viceroy.

The intelligence of the fall of Guanajuato, whilst it gave celebrity to the name of Hidalgo, created great consternation amongst the Spaniards of the capital. The new viceroy, however, Don Francisco Xavier Venegas, by his judgment and firmness, preserved public tranquillity in the capital. Don Felix Maria Calleja, who headed a brigade of troops stationed at San Luis Potosi, was intrusted with a command, and ordered to pursue Hidalgo. Nor was the superstition of the people overlooked; for some doubts having arisen with respect to the justice of the sentence of excommunication which had been pronounced against the leader of the insurgents, it was confirmed by Lizana and by the Inquisition. After remaining at Guanajuato until the 10th of October, Hidalgo, at the head of his army, advanced upon Valladolid, which was quietly taken possession of on the 17th of the same month. His army was now about sixty thousand strong, a force which he considered as sufficient to conquer the capital, and thus, by one decisive blow, to terminate the revolutionary struggle. He accordingly left Valladolid on the 19th; and at Las Cruces encountered a corps of observation under the command of Colonel Truxillo, assisted by Don Augustin Iturbide, then a lieutenant in the service of Spain. After a sanguinary contest, the royalists were defeated, and compelled to fall back upon the capital. Alarmed at the recent success and the near approach of the insurgents, Venegas drew upon the superstition of the people in support of the Spanish cause. The famous image of the Virgin of Remedios was brought and placed in the cathedral of Mexico. Thither the viceroy went in full uniform, and with all due pomp; and after imploring the Virgin to take the government into her own hands, he wound up his appeal by laying his staff of command at the feet of her image. But the aid of the Virgin was not required, for Hidalgo, after appearing before the city, to the astonishment of every one, withdrew his troops without striking a blow, and retreated towards Guanajuato. On the 7th November he came in contact with the outposts of the royal army at Aculco. A sanguinary action ensued, in which, from the superiority of their discipline and arms, the royal forces gained a complete victory. Hidalgo retreated to Valladolid, and then proceeded to Guadalaxara, where he was received with the greatest pomp and enthusiasm.

Capture and execution of Hidalgo, A.D. 1811.

At Guadalaxara Hidalgo proceeded with his usual activity to replenish his stores, recruit his forces, and bring cannon from San Blas, the principal Spanish arsenal on the western coast. He then advanced to the bridge of Calderon, which is 16 miles from Guadalaxara, and having fortified himself in a strong position, he awaited the approach of the royalists. On the 16th January 1811 the two armies were once more in sight of each other, and on the following day a general action took place. After various attacks, which the Mexicans repulsed with spirit, Calleja at last succeeded in carrying all their batteries; and Hidalgo was forced to withdraw them from the field. He withdrew to Saltillo, followed by about 4000 men. But on the 21st of March 1811 he was captured while setting out to the United States for the purpose of collecting arms and other necessaries. After a protracted trial he was shot on the 27th of July.

National junta.

After the death of Hidalgo, a guerilla war was carried on in various parts of the country; but as the leaders acted without concert, and no general engagement took place, it is unnecessary to follow it in its irregular course. Rayon being now left in command of the insurgent troops at Saltillo, retreated first to Zacatecas, and afterwards to Zitacuaro in the state of Valladolid, which he entered about the end of May 1811. At this period in the history of the revolution disaffection towards the Spaniards had become very general. Armed bands of insurgents overran the open country, and hardly a day passed without being signalized by a skirmish. Meanwhile Rayon was busily employed in furthering the scheme of a national junta, and on the 10th of September 1811 he accomplished his purpose. A junta, or central government, was installed, consisting of five members, who were elected by the ayuntamiento, in conjunction with the principal inhabitants of the town and district. Amongst the principles adopted by this new junta was the acknowledgment of Ferdinand VII. as sovereign of Mexico, provided he would quit his European dominions. But from documents published after the struggle for independence had terminated, we learn that these professions of adherence had no deeper origin than expediency. The intelligence of the formation of the junta of Zitacuaro excited enthusiastic hopes throughout Mexico; and from the first moment of its establishment, the Spaniards considered it as their most formidable enemy. Accordingly, towards the end of the year Calleja marched with all his forces against Zitacuaro, and arrived before it on the 1st of January 1812. On the following day he captured the town, and drove the junta to Sultepec, where it established a new seat of government; but Calleja inflicted signal vengeance on that place for affording shelter to the fugitives. He ordered the inhabitants to be decimated, the town to be burned, and the walls of the buildings to be levelled with the soil, the churches and convents alone being spared. By forced marches the royal forces now proceeded to Mexico, where they were anxiously expected by the viceroy, in order to check the progress of the curate Don Jose Maria Morelos.

Exploits of Morelos.

In October 1810 Morelos had been appointed captain-general of the provinces of the south-western coast, and had entered upon his duties at the head of about 1000 men. Advancing with this force upon Acapulco, he surprised and routed a well-appointed body of troops under Don Francisco Paris, the commandant of the district. By this brilliant exploit Morelos obtained so much celebrity, that numbers from every quarter flocked to his standard, and amongst others, Galeana, Matamoros, and three persons of the name of Bravo, one of whom, Don Nicolas, afterwards became so famous. The whole of the year 1811 was spent in a series of skilful manœuvres and petty engagements, in which the insurgents were generally successful.

Meanwhile intelligence reach Morelos of the arrival of the victorious royalists under Calleja; but nothing daunted by the circumstance, he determined to await the attack at Cuautla Amilpas, which is distant about 22 leagues from the city of Mexico. On the 19th of February Calleja made a general attack upon that town, but after a conflict which lasted eight hours, he was compelled to retreat, leaving five hundred dead behind him. From this day he abandoned all thought of risking another general assault; but erected batteries, and began to cannonade and bombard the town. Disease and severe famine soon began to diminish the numbers of the besieged, so that the commander-in-chief formed the resolution of retreating; and this he succeeded in accomplishing, with equal ability and success, on the night of the 2d of May. Calleja entered Cuautla some hours after his opponent had left it, and there, as usual, he perpetrated barbarities which will for ever leave a stain upon his reputation.

Subsequent proceedings of Morelos, A.D. 1812–13.

The bravery and resources which Morelos had displayed at the siege of Cuautla extorted admiration even from his enemies, whilst they became the theme of universal praise amongst his countrymen. Leaving Izucar, he proceeded to Tehuacan, into which he made a triumphal entry on the 16th of September 1812, having defeated three divisions of the Spanish army on his way. In the beginning of November he began to execute his design of conquering the whole province, and accomplished it by the capture of Acapulco in August of the following year.

Declaration of independence A.D. 1813.

During the absence of Morelos everything had been prepared by Matamoros for the meeting of the National Congress, which took place accordingly on the 13th of September 1813 in the town of Chilpanzingo. This assembly consisted of the original members of the junta of Zitacuaro, the deputies elected by the province of Oaxaca, and others again selected by them as representatives for the provinces in the possession of the royal troops. Exactly a month after the opening of the session, an act was published, declaring the absolute independence of Mexico.

Morelos defeated, A.D. 1813.

Besides the achievements already recorded, the years 1812 and 1813 had been distinguished by several other victories gained by the insurgent generals, Don Nicolas Bravo and Matamoros. But the time had now arrived for Morelos attempting a more decisive blow than any which had yet been struck. With seven thousand men and a large train of artillery, he left Chilpanzingo on the 8th of November, and after sustaining incredible fatigue and privations, arrived before Valladolid on the 23d of December.

History.

This place was defended by a formidable force under Brigadier Llano and Colonel Iturbide. Confident of success, Morelos ordered his troops immediately to advance to the attack, but they were driven back with loss. Next morning, during a general review which took place within half a mile of the walls, Iturbide made a sudden attack upon the Mexicans, and succeeded in totally routing the whole army, which lost its best regiments, and all its artillery. Morelos retired to Puruaran, where he was again completely defeated by Iturbide, on the 6th of January 1814. Here a number of prisoners were taken by the royalists, and amongst the rest Matamoros. Some Spaniards who had been taken in former engagements were offered by Morelos in exchange for him; but Calleja, who on the 4th of March 1813 had superseded Venegas as viceroy, refused to accede to any such proposal. Matamoros was accordingly shot, and by way of reprisal the Mexicans put to death all the prisoners in their hands.

Further reverses, and death of Morelos, A.D. 1814–1815.

Morelos now withdrew to the southern coast, and there began to recruit his forces with his characteristic activity and resolution. But his cause was destined to experience defeat upon defeat. Oaxaca fell into the hands of the royalists on the 28th of March 1814; whilst the Congress itself, expelled from Chilpanzingo, was forced to take refuge in the woods of Apatzingan, where it continued its labours, and on the 22d of October sanctioned the constitution known by that name. Morelos resolved to undertake an expedition to Tehuacan, where Teran had assembled a considerable force, for the purpose of placing it in greater safety. With only five hundred followers he commenced a journey of 60 leagues through a country occupied by several divisions of the royalists. He was surprised by two parties of Spaniards under Concha on the 5th of November 1815. He ordered Bravo immediately to continue his march with the main body, whilst he with a few men endeavoured to check the advance of the enemy. Most of his fifty followers abandoned him when the firing became warm; but not until only one man remained by his side did the royalists venture to advance upon one so far-famed for his personal courage. He was taken prisoner, and transferred to the capital after experiencing the most brutal treatment at the hands of the Spanish soldiery. After a trial, he was condemned to be shot, which sentence was carried int effect on the 22d of December 1815. He walked to the place of execution with the most perfect serenity; and after pronouncing this short prayer, "Lord, if I have done well, thou knowest it—if ill, to thy infinite mercy I commend my soul," he bound a handkerchief about his eyes, and met death with as much composure as he had ever shown when facing it on the field of battle.

The affairs of the insurgents fall into confusion, A.D. 1815–1817.

The loss of Morelos was irreparable, for he was the only patriot chief who could maintain unity of plan, concentration of purpose, and combination of movement. For several years, therefore, the history of the revolution consists only of disjointed details of a wide-spread guerilla war, in which success on either side led to no important results.

The Congress, which had escaped under the protection of Don Nicolas Bravo to Tehuacan, was dissolved by General Teran in December 1815. This step has been generally blamed as at least precipitate. There can be no doubt that it was attended by disastrous circumstances; for from that moment confusion became worse confounded; Victoria, Guerrero, Bravo, Rayon, and Teran, confining themselves each to his own separate circle, where they were crushed in succession by the superiority of the common enemy. Teran attempted to establish a government himself, but none would acknowledge it. Rayon, after he had commanded with great success in the mountainous parts of Valladolid, was taken prisoner, and confined in the capital until 1821. The fate of Don Nicolas Bravo was exactly similar to that of Rayon. Guerrero occupied the western coast, and here he maintained himself in the fastnesses of the Sierra Madre until 1821, when he joined Iturbide. Guadalupe Victoria was driven from his strongholds in his province of Vera Cruz, was deserted by all his followers, and was forced to skulk in the forest like a wild beast. For several years he lurked in the wildest recesses, never seeing the face of man, and living on the raw fruits of the earth and the bones of putrefying animals. When every one had thought him dead, he appeared in 1821, covered with hair and emaciated almost to a skeleton.

State of the country.

Some facts relative to the state of the country require to be mentioned. The cause of independence had been gradually gaining ground amongst the people, particularly since 1812, when the constitution, which was sanctioned by the Cortes of Cadiz, was extended to the transatlantic dominions of the crown. By the new constitution several important privileges had been conceded to the natives; amongst the rest, the right of electing the members of the Cabildo and the deputies to the Cortes. In law, also, matters underwent so complete a reform, that a Creole might now hope for a favourable decision, provided his cause was a good one. Thus by the new constitution the reverses sustained by the Creole leaders in the field were more than counterbalanced. Under the mild sway of Admiral Apodaca, who succeeded Calleja in the viceregal authority, all was done that could be done to secure the allegiance of the natives. The arrival of fresh troops from the Peninsula enabled him to extend his military ramifications throughout the whole country, and enforce obedience even at the most distant points. Thus, as we have seen, the revolutionary chiefs were successively crushed; and the facilities afforded to all who had embarked in the enterprise for reconciling themselves with the government by accepting pardon, reduced the number of those actually in arms in 1816, and the three following years, to a very inconsiderable amount.

Career of Mina, A.D. 1817.

After her last patriotic chiefs had quitted the open field, and sought refuge in the mazes of the forests, a deep gloom hung over the affairs of Mexico, which remained for a long time unbroken save by the sudden inroad of Mina.[1] This remarkable individual landed in Mexico on the 15th of April 1817. With about 200 men he left Soto la Marina, the place of his landing; and pushing forward to the confines of the table-land, defeated a body of 400 royalist cavalry. About the middle of June 1817 he reached the Hacienda de Peotillos; and on a little eminence which commanded the plain he cut to pieces a royal army 2000 strong with a force of only 172 men. On the 24th of June he reached Sombrero, having in thirty days traversed a tract of country 220 leagues in extent, and been three times engaged with an enemy greatly superior in numbers. In conjunction with the advanced guard of the insurgents and some recruits, he advanced upon San Juan de los Llanos, and on the 29th of June totally defeated the royalists under General Castañon. On the 24th of October, at nightfall, he took Guanajuato by storm, and penetrated into the very centre of the town. At this critical moment his troops refused to advance a step farther; and time being thus allowed the garrison to arm themselves, they attacked the insurgents, who, by the general's orders, dispersed with the utmost precipitation. Mina himself was taken prisoner three days afterwards, and sent to the head-quarters of General Linan, and there he was executed on the 11th of November, in his twenty-eighth year. Not long after his death the insurgent chiefs were driven off the field, and gradually disappeared; so that in July 1819 not one remained of those who had taken any lead in the revolution.

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[1] Don Xavier Mina, a famous Spanish guerilla chief, still more celebrated in Old Spain for his patriotic efforts to create a rising in favour of the Cortes at Pampeluna, subsequently to the dissolution of that assembly by the king.

State of the independent cause, A.D. 1819–1821.

The cause of Mexican independence seemed now to have sunk to such a low ebb, that the viceroy wrote in great confidence to the court of Madrid, representing the country as so tranquil and submissive to the royal authority, that he would answer for its safety without the assistance of a single soldier from Europe. But the appearances on which he relied proved altogether fallacious. The disbanded insurgents, mingling freely in the ranks of the Creoles, made proselytes to the principles of the revolution even in the royal camp itself. In private the bulk of the people were as warmly attached to them as ever. About the middle of 1820 accounts arrived in Mexico of the revolution in Spain, occasioned by the revolt of the army in the Isla de Leon; and it soon became public that orders had been sent to Apodaca to proclaim the constitution which Ferdinand VII. had been compelled to adopt. The era of 1812 was revived, and the public mind thrown into a ferment, which the viceroy, from his restricted powers, found it impossible to allay. Besides, the Mexicans were divided amongst themselves, one party professing a sincere adherence to the constitution, whilst another class was as strongly attached to the old system. Necessity of course compelled the viceroy to take the oath to the constitution; but he favoured those who were opposed to it, and took secret measures for effecting its subversion. General Armigo, who was partial to the constitution, was dismissed from the command of the army stationed between the capital and Acapulco, and his place offered to Don Augustin Iturbide, a native Mexican, to whom allusion has already been made. The proposal was accepted, and Iturbide left the capital in February 1821 with half a million of dollars, destined for embarkation at Acapulco, but with intentions very different from those by which the viceroy supposed him to be actuated.

Second Mexican revolution, A.D. 1821.

Having arrived at a town called Iguala, situated about 120 miles from the capital, Iturbide took possession of the money; and on the 24th of February he commenced the second Mexican revolution by proposing a new government, which is well known under the title of "the plan of Iguala." His force of 800 men unanimously took the oath of fidelity to the "plan," whilst a copy was transmitted to the viceroy and to all the governors of provinces. This celebrated document consisted of twenty-four articles, the principal points embodied in which were,—a declaration of Mexican independence; the recognition of the Catholic religion as the national creed; the establishment of a constitutional monarchy; the formation of a junta of government; an offer of the crown to Ferdinand VII., and in the event of his refusal, to the Infantes Don Carlos and Don Francisco de Paula, provided any of them would consent to occupy the throne in person; an abolition of castes and of the despotism of military commandants; the formation of an army for the support of religion, independence, and union, and for guaranteeing these three principles, whence it was to be called the army of the three guarantees; a general amnesty to all who should give in their adhesion to the "plan;" and other provisions of less importance.

Success of Iturbide.

When the viceroy learned the defection of Iturbide, he concentrated a force upon the capital for the purpose of defending it; but hesitating to put himself at the head of the troops, the Europeans deposed him, and placed at the head of affairs Novella, an officer of artillery. By this unwise proceeding a schism was created in the capital, which afforded Iturbide time for prosecuting his scheme. He effected a junction with General Guerrero, and from this moment his success became certain. On his route to the Baxio, great numbers of men and officers joined his standard. Before the month of July, the whole country had recognised his authority, with the exception of the capital. On his march to invest the city of Mexico, intelligence reached Iturbide that the new constitutional viceroy and political chief, O'Donoju, had arrived at Vera Cruz. He immediately requested an interview with this functionary, and allowed him to advance as far as Cordova, where a meeting took place. O'Donoju agreed to the plan of Iguala, and in the name of his master he recognised the independence of Mexico. Such was the treaty of Cordova, which was signed by Iturbide, "as the depository of the will of the Mexican people," and by O'Donoju, as the representative of Spain, on the 24th of August 1821. By virtue of this treaty Iturbide obtained possession of the capital, which he entered in triumph on the 27th of September. A provisional junta of thirty-six persons then elected a regency of five, with Iturbide at their head. He was at the same time created generalissimo and lord high admiral, and had assigned to him a yearly salary of L.24,000.

Usurpation of Iturbide, A.D. 1822.

The career of Iturbide had hitherto been triumphant; but scarcely had the first Mexican Cortes met on the 24th of February 1822, when its members split into three distinct parties: first, the Bourbonists, or those who wished to establish a constitutional monarchy with a prince of the House of Bourbon at its head; secondly, the Iturbidists, who aimed at elevating Iturbide himself to the throne; and, thirdly, the republicans, who desired a central or federal republic. The Bourbonists soon ceased to exist, the Cortes of Madrid having declared the treaty of Cordova "to be illegal, null, and void, in as far as the Spanish government and its subjects were concerned." A protracted contest ensued between the two remaining factions, and resulted in the defeat of the Iturbidists. Nevertheless, the republican party were forced to yield to the wishes of the mob and the army, and to declare Iturbide emperor on the 19th May 1822. The new monarch assumed the title of Augustin I.

Conduct of the new emperor.

Iturbide began his reign by demanding the right of appointing and removing at pleasure the judges of the supreme court; he claimed a veto upon all laws, not excepting the articles of the constitution then under discussion; and he recommended the establishment of a military tribunal in the capital, with powers very little inferior to those exercised by the Spanish commandants during the revolution. This attack upon their liberties the Congress indignantly repulsed. Such decisive conduct led at once to an open rupture. Upon the night of the 26th of August, fourteen deputies of liberal principles were, by the emperor's orders, arrested and thrown into prison. This bold step was followed by a series of reclamations and remonstrances on the part of the Congress; but Iturbide sent an officer to the hall of the Congress with a simple notification that the assembly had ceased to exist, and an order to dissolve it by force should any resistance be offered to his authority. But no compulsion was required. The deputies dissolved their sessions at once, and the doors of the chamber were closed by the officer. This took place on the 30th of October 1822. On the same day a proclamation appointed a new legislative assembly, called the Instituent Junta, consisting of forty-five members, selected by Iturbide himself. This assembly, however, never possessed any influence in the country; and the tranquillity which Iturbide enjoyed proved of short duration. Matters were brought to a crisis by the defection of General Santa Anna, governor of Vera Cruz, towards the close of the year 1822. The far-famed Victoria, quitting his hiding-place in the mountains, was invested by the rebels with the chief command, and rallied the natives in great numbers round his standard. General Echavari, who had been despatched by the emperor to invest Vera Cruz, made common cause with the garrison of that city, and induced his whole army to follow his example. On the 1st of February 1823 the act of Casa-Mata was signed, by which the armies pledged themselves to effect the re-establishment of the national representative assembly. Bravo, Guerrero, and Negrete now joined the republican army, and the defection became so general that Iturbide tendered his resignation on the 19th of March, and stated at the same time his intention of quitting the country. The Congress refused to accept of the abdication, as that would have implied that he had legal right to the crown; but they willingly allowed him to quit the kingdom with his family, and assigned him a yearly pension of about L.5000. He set sail in a ship freighted by government to convey him to Leghorn.

His death, A.D. 1824.

The old Congress was immediately convoked; a provisional government was established; and an executive, composed of Generals Victoria, Bravo, and Negrete, was appointed. They conducted the affairs of the country until a new Congress was assembled in August 1823; and in October 1824 the federal constitution was definitively settled by the latter. Meanwhile Iturbide, the ex-emperor, had proceeded to Leghorn, had subsequently visited London, and on the 11th of May 1824 had embarked with his family for Mexico. Disregarding the sentence of the Congress which had outlawed him, he landed about the middle of July at Soto la Marina, where he introduced himself in disguise and under a feigned name. But he was apprehended by General Garza, and shot a few days afterwards.

Form of government.

The form of government adopted by the representatives of Mexico was that of a federal republic, upon the plan of that of the United States, with a few unimportant deviations. The confederation, consisting of nineteen states and four territories, was cemented into one body politic by certain general laws and obligations, contained in the federal constitution of the 4th of October 1824, of which an outline will be afterwards given. Each state and territory, however, retained the uncontrolled management of its own internal affairs. Victoria was elected president and Bravo vice-president.

Subsequent disorders and revolutions.

But the hopes which had been formed regarding the peace and prosperity of Mexico proved altogether fallacious. Repeated revolutions continued to disturb and agitate the country. From the moment at which the war of independence commenced the nation became divided into two parties,—natives and Guachupines, or European Spaniards. The former consisted of those who wished to establish the independence of Mexico; the latter were warmly attached to the dominion of Spain. To these two parties succeeded the Imperialists and Republicans; and, lastly, came the Centralists and Federalists, which went under the sobriquets of Escosses and Yorkinos, appellations derived from two masonic societies, and synonymous with *aristocrats* and *democrats*.

Pedraza elected president, A.D. 1828.

The time was now approaching when it became necessary to find a successor to Victoria as president of the republic; and General Gomez Pedraza, a very efficient member of the Mexican cabinet, was brought forward as a candidate by the Escosses party. After an arduous contest, he was elected president by a majority of two votes over Guerrero, the representative of the Yorkinos. But the disappointed party was loud in its denunciation of the successful candidate. His friends were accused of bribery and corruption, and even charged with procuring the interference of the military in some of the states. By a singular anomaly in the constitution of Mexico, a period of nearly seven months is allowed to elapse before the president who has been elected can take possession of the government; so that time was thus afforded the defeated party to collect its strength, and prepare for a vigorous effort to annul the election by an appeal to arms. It was at this time that General Santa Anna set out from Jalapa at the head of about 800 men, and took possession of Perote. There he published a manifesto charging Pedraza with having succeeded in his election by fraudulent means. He further proposed that the people and army should annul the election of Pedraza; that the Spanish residents should be banished as the primary cause of the grievances from which the Mexicans suffered, and that Guerrero should be declared president. This audacious "plan" was vigorously protested against by Victoria; and addresses reprobating the conduct of Santa Anna poured in from all quarters. The mass of the population, however, remained undisturbed, and Guerrero himself resolved quietly to await the course of events.

Expulsion of the Spaniards, A.D. 1828.

From a feeling of hostility towards the natives of Spain, which prevailed pretty generally throughout Mexico, matters were very speedily brought to a crisis. On the night of the 30th November 1828, a battalion of militia, headed by the ex-Marquis of Cadeña, and assisted by a regiment under Colonel Garcia, took possession of the artillery barracks at the Acordada, surprised the guard, and seized the guns and ammunition. Next morning the insurgents were joined by General Lobato a partizan in the revolutionary war, Zavala the ex-governor of Mexico, the Yorkino deputy Cerecero, a party of militia, and a number of officers. By the 2d of December the insurrection had made alarming progress, and a sanguinary contest ensued, which ended on the 4th in the overthrow of the government troops. The city was then given up to be pillaged. Vengeance was chiefly directed against the Spaniards; but all who were supposed to possess wealth fell victims to the rapacity of an unbridled mob. These disgraceful scenes continued for two days, and property to a very great amount was destroyed or changed owners. Pedraza formally resigned his office, and was allowed to quit the territories of the republic. At a new Congress, assembled on the 1st January 1829, Guerrero was declared duly elected, and General Anastasio Bustamante, a distinguished Yorkino leader, was associated with him as vice-president. Santa Anna was invested with the supreme military command of the republic.

Invasion of Barradas, and abdication of Guerrero, A.D. 1829.

The first event which disturbed the country after the elevation of Guerrero, was the arrival of an invading force from Cuba, under Barradas, in the summer of 1829. Santa Anna, however, routed the invaders, and took Barradas himself prisoner. But Guerrero was now destined to taste the cup which he had mixed for his predecessor. Early in December 1829 Bustamante, the vice-president, flew to arms, and having placed himself at the head of the army of Mexico, which was stationed in the state of Vera Cruz, he advanced upon the capital, everywhere denouncing the abuses and usurpations of Guerrero. Guerrero appealed to the Congress for support; but it was all in vain: he was ultimately compelled to abdicate. The army then elected Bustamante as his successor; whilst Santa Anna, following the example of Guerrero, retired to his estates, and tranquillity was soon restored.

Fall of Bustamante; election of Santa Anna, A.D. 1833.

At this period it required no great gift of prophecy to predict that even the shadow of the constitution of 1824 would not long survive. Mexico was now beyond all doubt subjected to a military despotism; and a pretext or cause for prostrating Bustamante in his turn could not long be wanting. It was enough that the daring, crafty, and cruel Santa Anna was living in retirement and hatching new schemes of revolt. From that period Mexico has presented a kaleidoscopic exhibition of factions and parties. It would require volumes to detail the series of manœuvres, of *gritos* and insurrections, which seated Santa Anna ultimately in power, and made him the representative of that amalgam of all parties which has been designated by a cant term in which the most incongruous ideas are jumbled together. In July 1832 the Ayuntamiento and people of San Felipe de Austin unanimously gave in their adherence to the plan of Vera Cruz, and to the principles of the republican party, headed by General Santa Anna. This example was followed by other states; and Santa Anna assumed the reins of government. In April following he expelled the Congress; and in 1835 Gomez Farias, who had been elected vice-president, was driven into exile. Santa Anna was also successful in his new "plan;" and centralism, with a *de facto* dictatorship, succeeded to the federal republic. The states were converted into departments, and the legislatures cut down to a council of five. This new order of things was acknowledged by the whole country, with the exception of Texas, which was warmly attached to federalism. It will appear, however, from the sequel, that the disaffection of this lately settled territory led to important results.

Proposed separation of Coahuila and Texas, A.D. 1833.

At a meeting of the people of Texas in 1833 a constitution had been drawn up in which, amongst other important matters, they pointed out the necessity of a separation from Coahuila. The chief reasons assigned for the contemplated disunion were, the dissimilarity between Coahuila and Texas, in soil, climate, and productions, in common interests, and partly in population, so that laws happily constructed for the benefit of Coahuila, and conducive to its best interests, might be ruinous to Texas. The seat of government was also stated to be too remote, being fixed at Saltillo, and the inhabitants of that part of the state were almost exclusively of Spanish descent. Colonel Austin, who had for many years been member of Congress for Texas, was charged with the duty of submitting to the general government in Mexico the new constitution which had been formed; but finding it difficult or impossible to effect his object, he wrote a letter to some of his friends in Texas, in which he did not conceal his sentiments as to the necessity of Texas taking matters into her own hands, and doing herself justice. This letter was intercepted, and first awakened the jealousy of the Mexican government.

Causes of the rupture with Mexico.

But before proceeding to narrate the leading incidents of the struggle with Mexico it is necessary to premise, that the unappropriated lands, although state property, could not be granted to any one without the sanction of the general government. At this time a great rage for land speculation existed, not only in Mexico, but in the United States, and an extensive system of fraud was the consequence. In 1834 a company of speculators, many of whom belonged to or had come from the latter country, induced the legislature of Coahuila and Texas to grant them 400 square leagues of public land for the sum of 20,000 dollars. The transaction was disavowed, and the grant annulled, by the Mexican government; and it led to the dispersion of the local legislature, and the temporary imprisonment of the governor Viesca.

About the same time an attempt to establish customs was forcibly resisted by the colonists. This, together with a demand for the persons of those who had been concerned in the grant of the 400 leagues of land, were the immediate precursors of hostilities. Viesca issued proclamations and addresses calling the inhabitants of the state to arms against the encroachments of that military power which threatened, he said, their very existence, not only as a state, but as a people. Santa Anna was stigmatized as a dictator, and death was denounced against all his supporters who should enter Texas. Taxes were refused; the custom-house officers were expelled; and the laws of Mexico were set at defiance. In these circumstances Santa Anna, who had succeeded in gaining all the other states of the republic, found it necessary to turn his attention to Texas.

Hostilities; declaration of independence, A.D. 1835–1836.

In September 1835 General Cos, the confidential friend and brother-in-law of the central chief, landed at Compano at the head of 400 men destined to reinforce the garrison of San Antonio de Bejar. But he was foiled in his attempt to defend that city against the Texians, and was forced to retire from the province in October. Early in March 1836 a convention of delegates from the various settlements of Texas, having assembled at Washington, issued a formal declaration of independence, setting forth the grievances which impelled the people to take that step. This declaration was signed by forty-four delegates, of whom only three or four were Mexicans by birth. When this decisive step was taken, the people of Texas undoubtedly supposed that the internal divisions of the country would afford sufficient employment for the arms of Santa Anna; forgetting that there existed in Mexico an inveterate prejudice against the United States colonists, which might induce them to overlook for a time all minor differences, and unite as against a common enemy. Hence the defeat of Cos actually extended the influence of Santa Anna, and he was thus enabled to bring nearly the whole resources of Mexico to bear upon Texas. Early in February 1836 he established his head-quarters on the Nueces, to the eastward of the Rio del Norte. By his plan of operations he proposed to advance in two columns, one directed against San Antonio, and the other against La Bahia, which place was lower down the coast; intending by this means to intercept all communication between the Americans and the Gulf. His troops in the first of these enterprises were repulsed; in the second they were successful, but disgraced their triumph by massacring 500 captives in cold blood.

Total defeat of the Mexican army, A.D. 1836.

This military execution caused much excitement, and exasperated the Texians in the highest degree. They suddenly ceased to retreat, and General Houston, having rapidly counter-marched a distance of about 60 miles, came up with Santa Anna. On the 21st of April, near the banks of the San Jacinto, a fierce and sanguinary conflict took place, in which the Mexicans were defeated with great slaughter, and above 700 taken prisoners, amongst whom was the commander-in-chief himself. This unexpected event totally changed the aspect of affairs; and the success of the Texians stimulated their zeal and activity. Many of the more pacific of the colonists had sought refuge in the neighbouring states; but their place was speedily supplied by numerous adventurers from the United States. On the 15th of May a convention was held at Velasco in Texas, where it was stipulated that hostilities should cease; that the Mexican army should quit Texas; and that Santa Anna should be sent to Vera Cruz, upon condition of his agreeing neither to take up arms against the Texians, nor to exercise any influence to cause them to be taken up during the struggle for independence.

The Texians assert their distinct nationality.

The inhabitants of Texas now set themselves to assert their distinct nationality, by electing their own officers, equipping their own army and navy, and guarding their own frontiers. At the same time their independence was publicly recognised by Great Britain, France, and the United States. For several years Mexico was too much engrossed with internal disturbances, and with the political contests of her magnates, to attempt to reconquer her lost province. At length, in 1844, the commencement of negotiations for engrafting Texas on the American Union roused her from her lethargy. She protested loudly against the unjust attempt of the United States to rob her of part of her dominions. The president Herrera attempted, at the request of the American government, to settle the difficulty by negotiation; but so violent was the popular indignation against such lenient measures, that on the 30th December 1845 he was forced to resign the presidential chair to General Paredes, the darling of the Mexican mob.

Hostilities between Mexico and the United States, A.D. 1846–47.

The new president began his sway by raising money and levying troops for the invasion of Texas. To General Ampudia was intrusted the protection of the northern frontiers. Accordingly, on the 11th April 1846 he settled down with a large force at Matamoros on the Rio Grande, and confronted an American army stationed, under General Taylor, on the opposite bank of the river. In a short time skirmishes between these two bodies of troops began the war, and were the signal to the United States for despatching a large force against Mexico. "An army of the West" and an "army of the Centre" were organized under the respective commands of Generals Kearney and

Wool. Commodore Conner in the Gulf of Mexico, and Commodores Stockton and Sloat in the Pacific, were ordered to co-operate with the land forces. Meanwhile General Taylor had occupied Matamoros on the 18th May, and was actively engaged in levying recruits and in establishing a base line of operations along the Rio Grande. He then advanced southward along the main highway into the interior, and sat down before the strong city of Monterey, the key of the northern provinces of Mexico. After a desperate assault, which lasted two days, his force of 7000 strong captured the town from nearly 10,000 Mexicans on the 24th of September. By this time Santa Anna, with the connivance of the American Congress, had returned to Mexico, and had supplanted General Paredes in the chief power. But contrary to the expectation of the United States, he allowed himself to be swayed by the popular feeling, and began to muster the full strength of the nation for the war. Advancing northward towards the close of 1846, he concentrated a force of 20,000 at San Luis Potosi, with the evident intent of attacking Taylor's extended base of operations in the valley of the Rio Grande. It was not long therefore before he set out with his entire army along the road to Saltillo. On the 22d of February 1847 he came up to Taylor's army of 5000, closely drawn up in the narrow gorge of Angostura, and ready to dispute his advance. A desperate attempt to outflank the American army was immediately made, and was successfully repulsed. On the morrow the mighty force of Santa Anna shattered itself by vain efforts to force the pass, and towards evening commenced a retreat to San Luis Potosi. Shortly before this California had been finally wrested from Mexico by Captain Fremont and Commodore Stockton. New Mexico had also been subdued in the preceding year by General Kearney.

Capture of the city of Mexico, and conclusion of the war, A.D. 1847–48.

In the meantime the American Congress, intent upon striking a blow at the heart of Mexico, had intrusted the command of an expedition against the Mexican capital to General Scott. With the most patient foresight, that eminent commander occupied a considerable time in mustering all the available strength of his country, and in providing resources against every possible emergency. At length, on the 9th of March 1847, he landed near Vera Cruz, and invested that city both by sea and land. After a close bombardment of eight days the besieged garrison were forced to capitulate. Scott then pressed forward towards the capital, and, as he approached Jalapa, found the army of Santa Anna entrenched within an elaborate line of defences on the wild road at Cerro Gordo. After a hard-fought assault of two days the Mexican troops were cut to pieces, and driven in a headlong flight towards the metropolis. The American general advanced without further opposition to La Puebla. There he lay for some time recruiting his forces and concerting his plans for the assault upon the city of Mexico. On the 7th of August he was again on the march. After overwhelming several attempts to check his advance at Contreras, Churubusco, El Molino del Rey, La Casa Mata, and Chapultepec, he began the final assault upon the capital on the 12th of September, and penetrated within the walls on the following day. By retreating during the night, the Mexican army left the fate of their country in the power of the Americans. On the 2d of February 1848 the war was closed, and New Mexico and Upper California were ceded to the United States by the peace of Guadalupe Hidalgo.

Soon after the conclusion of this treaty, Santa Anna, seeing that his power was on the wane, sought an asylum in Jamaica. General Herrera was elected president of the republic. But both under him and under his successor, General Arista, the country continued in a state of the wildest anarchy. At length, in 1852, it had become a prevalent opinion among the Mexicans that a strong central government alone could save them from ruin. Santa Anna was allowed to be the fit instrument for effecting the desired change. Accordingly, in the same year, that dexterous politician and able general was recalled from exile by common consent. In December 1853 he was elected perpetual president, with the authority of dictator, and the title of Most Serene Highness. But the extraordinary powers with which he was invested failed to harmonize those discordant feelings which sprung from difference of political opinion on the one hand, and difference of race on the other. On the 22d of January 1854 a revolution, under General Juan Alvarez, broke out at Acapulco, absorbed within its ranks malcontents of every description, and spread with resistless rapidity through several states in the direction of the capital. Force and policy were alike unable to check it, and at length, on the 9th of August 1855, Santa Anna abdicated and retired to Havanna. In September Juan Alvarez was raised to the provisional presidency, but resigned in December in favour of Ignacio Comonfort, who received the title of president-substitute. Scarcely had the new potentate formed his ministry, when he was assailed by conspiracy. Early in 1856 an insurrection, headed by Haro y Tamariz, enlisted in its cause a formidable number of the clergy, magistrates, and destitute workmen. It was suppressed, however, by Comonfort on the 22d of March.

III.—STATISTICS OF MEXICO.

Mexico is bounded on the N. by California, New Mexico, and Texas; E. by the Gulf of Mexico and the Caribbean Sea; S.E. by British Honduras and Guatemala; and S.W. and W. by the Pacific Ocean. Its greatest length in a N.W. and S.E. direction, from San Diego to the extreme S. part of Chiapas, is about 1987 miles, and its greatest breadth about 1128 miles. Its area is estimated at 829,900 English square miles, and it has a coast line of about 5830 miles in length. A great portion of Mexico is occupied by the Cordilleras, which run through its whole length, rendering the surface extremely varied. On entering this country from the S. the chain divides into two great branches, the western extending along the coast of the Pacific, and the eastern along that of the Gulf of Mexico, and afterwards subsiding into the plains of Texas. The vast tract of country between these branches, comprising about three-fifths of the entire area of the territory, consists of a central table-land called the plateau of Anahuac, 6000 to 8000 feet in general elevation; and hence its climate, though mostly within the tropics, is decidedly temperate. This region is crossed in various directions, or divided into sub-plateaus by numerous chains of mountains, some of which rise to the height of 17,000 feet above the level of the sea. The surface, however, is not broken by many transverse valleys, and in some parts there are extensive districts quite destitute either of depressions or elevations. Some of the peaks rise to a great elevation, towering far above the central plateau: the principal of these are Popocatepetl, 17,735; Orizava, 17,388; Yxtaccihuatl, 15,700 feet above the sea-level. These and many others of the Mexican mountains are volcanoes; the first is continually burning, but for centuries has ceased to eject from its crater anything but smoke and ashes. Luminous exhalations constantly irradiate the summit of Orizava. In 1545 an irruption took place, and the crater continued to burn for twenty years. In the same province (Vera Cruz) is the volcano of Tuxtla, in which a considerable irruption took place in 1793, the ashes of which were carried as far as Perote, a distance of 57 leagues. On the western side of the city of Mexico are the volcanoes of Jorulla and Calima, the latter of which throws up smoke and ashes, but has not been known to discharge lava. Jorulla, which is situated between Calima and the city of Mexico, is of much more recent origin than any of the others. It was thrown up *en masse* from a fertile plain having an elevation of 2890 feet, to the height of 4149 feet above the sea-level.

Geology. While in the Old World granite, gneiss, mica schist, and clay-slate often form the central ridges of the mountain chains; these rocks seldom appear at the surface of the Cordilleras of America, being there covered by masses of porphyry, greenstone, amygdaloid, basalt, obsidian, and other rocks of the same class. The granite, which here generally forms the lowest stratum, appears at the surface in the little chain that borders the Pacific Ocean, and which on the side of Acapulco is separated from the mass of high country by the valley of Peregrino. The beautiful port of Acapulco is a natural excavation in granitic rocks. As we ascend towards the table-land of Mexico, we see it rise through the porphyry for the last time, between Zumpango and Sopilote. Farther to the east, the mountains of Mixteca and of Zapateca, in the province of Oaxaca, are formed of the same rock, which is there traversed by veins of auriferous quartz. The great central plateau of Anahuac, between the fourteenth and twenty-first degrees of latitude, appears like an enormous dyke of porphyritic rocks, distinguished from those of Europe by the constant presence of hornblende and by the absence of quartz. These rocks contain immense deposits of gold and silver. Basalt, amygdaloid, trap, gypsum, and primitive limestone, however, form the predominating rocks. The strata succeed each other here in the same order as in Europe, excepting that syenite alternates with serpentine. The secondary rocks equally resemble those of the Old World; but hitherto no considerable beds of rock-salt or of coal have been discovered in the plateau of Mexico. In some parts the porphyry presents itself in gigantic masses, which assume extraordinary shapes, resembling ruined walls, bastions, towers, and the like. The porphyritic traps which terminate the mountains of Jacal and Oyamel appear in columns, and are crowned with pine trees and oak, which materially add to their picturesque appearance. It is from these mountains that the ancient Mexicans obtained the obsidian, of which they formed their sharp-edged instruments. The Cobre de Perote is a porphyritic mountain, resembling an ancient sarcophagus surmounted by a pyramid at one end. The basalts of La Regla, of which the prismatic columns, 100 feet in height, have their central parts harder than the rest, form the native decorations of a very beautiful cascade.

Mines. The mines of Mexico were wrought long before the arrival of the Spaniards; the natives of Mexico, like those of Peru, being well acquainted with the use of metals. Nor were they contented with such specimens as they found scattered on the surface of the earth or in the ravines of mountain torrents, but had also learned to dig for them, and to trace the metallic veins in the interiors of the mountains. Gold and silver vases, and other specimens of jewelry, made in Mexico, were sent to Spain by the first conquerors as evidence of the mineral wealth of the country. The dependent tribes paid their tributes to the sovereign in a species of metallic currency, which, though not stamped, was yet the representative of a standard value. The mines of Mexico are nearly all on the top or on the western slope of the great Cordillera, and the mining region occupies an area of about 12,000 square leagues. On the country becoming settled after the revolutionary disturbances, especially about the year 1825, the Mexican mines were eagerly seized as objects of speculation by British and American capitalists. In consequence, however, of bad management, or the wild spirit of gambling which assumed the place of prudent commercial enterprise, the holders of stock were disappointed in their expectations, and sometimes ruined. The enormous cost of transporting heavy materials in a country where there are no navigable rivers extending into the interior, and where the usual mode of carriage is on the backs of mules, by wretched roads, over mountains, and through ravines, has often absorbed large portions of the original capital before the proprietors could even commence the working of their mines. Many of the first British and American speculators were thus ruined; but their successors are beginning to reap the benefit of their expenditure, and throughout the republic steam-engines and the best hydraulic apparatus are now employed. The annual average produce of the mines before the revolution was estimated at about L.5,000,000, and between the revolution and the year 1825 at nearly L.2,300,000. The annual produce of silver alone is now estimated at about L.7,000,000, and of gold about L.6,500,000. There are also some twenty-five quicksilver mines, yielding from 250,000 to 300,000 lbs. of metal annually. Besides the precious metals, Mexico abounds in other ores. Iron is plentiful in the states of Valladolid, Zatatecas, and Jalisco, but has hitherto been little worked. Copper is found in a native state in Valladolid, and also to some extent in Guanajuato. Tin, though obtained in mines, is principally extracted from the water-carried earth found in the deep ravines. A combination of these two metals was used by the ancient Mexicans to form their tools and weapons; and they had acquired the art of tempering them so as to render them equal in utility to iron, or even to steel. Lead is found, but the mines are very little worked. Zinc, antimony, and arsenic also exist; but neither cobalt nor manganese have as yet been discovered.

Rivers. Mexico is singularly deficient in large rivers. The Rio Grande del Norte, which forms its N.E. boundary, is the largest, having a length of about 1800 miles. The principal affluents of the Rio Grande are the Conchas, the Salado and Sabinas, and the San Juan rivers. The Santander, Tampico, Panuco, and Usumasinta, are the chief of those flowing into the Gulf of Mexico; while the Rio Yompex, the Balsas or Zacatula, the Aztla, Santiago, Culiacan, and the Rio del Fuerta, fall into the Pacific. A small portion of the lower course of the Colorado is in this territory.

Lakes. The lakes of Mexico are numerous, and some of them are of considerable size. Lake Chapala in Jalisco covers an area of 1300 square miles, and Lake Terminos, which, however, is more properly an arm of the sea, has an area of about 2200 square miles. Lakes Pascuara in Michoacan, and those of Mextitlan, Cayman, and Parras, are all of large size. The valley of Mexico contains five lakes, into which the various streams of the district flow. These cover an area of 160 square miles, and are drained by a canal cut through rock 12 miles in length, 150 feet deep, and 300 feet wide, having its embouchure in the Rio Panuco.

Climate. Mexico, as regards climate, is usually divided into the *tierras calientes*, *tierras templadas*, and *tierras frias*. The first, or hot regions, include the low grounds, or those under 2000 feet elevation, on the east and west coasts. The *tierras calientes* of the west are less extensive than those of the east, as the western arm of the Cordilleras approaches nearer to the sea. The mean temperature of this region may be estimated at 77° Fahr. It is especially suited for the growth and cultivation of sugar, indigo, cotton, and bananas. The *tierras templadas*, or temperate regions, are of comparatively limited extent, and occupy the slope of the mountain chains which bound on either side the central table-land. They extend from about 2500 miles to 5000 feet in elevation, and the mean temperature is from 68° to 70° Fahr. Extremes of heat and cold are there equally unknown. The Mexican oak, and most of the fruits and cereals of Europe, flourish in this genial climate, the humidity of which produces great beauty and strength of vegetation. The *tierras frias*, or cold regions, include all the vast plateau elevated 5000 feet and upward above the sea, and have a mean temperature of about 62° Fahr. In the city of Mexico, at an elevation of 7400 feet, the thermometer has sometimes, though rarely, fallen below the freezing point.

In the coldest season the mean temperature of the day varies from 45° to 50° Fahr., while in summer the thermometer seldom rises above 75° Fahr. At a greater elevation than 8000 feet the climate is severe and disagreeable. Under the parallel of Mexico the line of perpetual snow varies from 14,000 to 15,000 feet above the sea-level. Vegetation here is not so vigorous as in the other two regions, and the plants of Europe do not succeed so well as in the *tierras templadas*. In the tropical regions, and as far north as 28° N. Lat., there are only two seasons; that of rain, lasting from June or July to September or October, and the dry season, continuing from October to the end of May. From the parallel of 24° to that of 30° the rain falls less frequently, and continues a shorter time, but the deficiency is compensated by the snow, which, from the 26th degree of latitude northwards, is deposited in considerable quantities.

The climate of the provinces denominated *internas*, and which are situated within the temperate zone, is distinguished by a striking inequality in the temperature of the different seasons; the winters being very cold, whilst the summers are comparatively very warm. To this, as well as to other local causes, must be attributed the aridity which characterizes a considerable portion of the plateau of Anahuac. There are few springs in the mountains; and the water, instead of collecting in little subterranean basins, filters through the earth or porous rocks, and loses itself in crevices formed by volcanic eruptions. The evils arising from aridity have increased since the Europeans first took possession of Mexico. The conquerors not only destroyed trees without supplying their place by young plants, but by artificially drying up extensive tracts of country, they occasioned a still more important evil. The muriates of soda and of lime, the nitrate of potass, and other saline substances, cover the surface of the soil. Still a great part of Mexico may be classed with the most fertile countries of the earth, for there every species of vegetable production is found, or may be successfully cultivated. On the ascent from Vera Cruz, climates, to use an expression of Humboldt's, succeed each other in layers; and the traveller passes in review, in the course of two days, the whole scale of vegetation, from the parasitic plants of the tropics to the pines of the arctic regions. In some parts, however, the climate is very insalubrious. The humidity of the coasts favouring the putrefaction of a prodigious mass of organic substances, originates diseases which attack Europeans and others not familiarized to the climate; indeed, under the burning sun of the tropics, the unhealthiness of the air is almost invariably a sure indication of extraordinary fertility in the soil. Nevertheless, excepting the seaports and some of the deeper valleys, where intermittent fever is very prevalent, Mexico ought, upon the whole, to be considered as a healthy country.

Zoology. The zoology of this interesting country has only hitherto been partially explored, and what is known relates chiefly to ornithology. Of one hundred and thirteen species of land birds ascertained to be natives of Mexico, sixty-eight seem to be peculiar to that country, eleven likewise natives of South America, and thirty-four of other parts of North America. The water birds that have been examined present no novelty, as all can be identified with the species distributed generally over North America. Among the wading birds are two beautiful species of tiger bitterns, formerly unknown to naturalists. The quadrupeds, insects, &c., are as yet little known. Deer and several varieties of antelopes are found on the table-lands, and the bison ranges in vast herds through various parts of Mexico. The domestic animals introduced by the Spaniards have increased to such a degree, that immense numbers of them run wild through the country. The wool of the sheep is of inferior quality; but this is attributable more to neglect and mismanagement than to any peculiarity in the climate. Mules are very abundant, especially in the mining districts.

Agriculture. From the great range of climate in Mexico, the vegetable productions must necessarily be very varied. "Indeed," says Humboldt, "there is scarcely a plant in the rest of the world which is not susceptible of cultivation in one or other part of Mexico; nor would it be an easy matter for the botanist to obtain even a tolerable acquaintance with the multitudes of plants, scattered over the mountains, or crowded together in the vast forests at the foot of the Cordilleras." The soil is in many parts of extraordinary fertility, and, where well watered, produces abundant crops with very little labour. The most important of the agricultural productions is maize or Indian corn, which constitutes the principal food of the inhabitants as well as of most of the domestic animals. This valuable grain is almost everywhere cultivated with success, and in some favourable spots its fecundity is very remarkable; eight hundred *fanegas* for one of seed having occasionally been obtained. Where irrigation is practicable, from three to four hundred for one is the ordinary ratio of increase; but where the crop depends upon the season it is more variable, and in some parts one good year in ten is all that is expected, the intervening years producing only forty or fifty bushels for one sown. Oats are little cultivated in Mexico, but the wheat and barley of Europe have been naturalized here. The former succeeds well throughout the table-land; but both in the *tierras calientes* and on the eastern and western slope of the Cordilleras, the ear does not form. The success of the crop on the table-land depends almost entirely upon the timely commencement of the rainy season; for if the dry weather continue beyond the middle of June, unless the grounds can be watered by artificial means, the crops of wheat, barley, and maize are destroyed by drought. Irrigation is therefore the great object of the Mexican farmer; and in the formation of reservoirs, canals, and the like, vast sums have been expended on the principal estates. The average annual produce of the whole of the corn lands of Mexico is estimated at twenty-five bushels for one; while in certain parts of the country, during favourable years and where the irrigation is good, from sixty to eighty bushels for one have been produced. At Chilula, near Puebla, the increase is stated at forty for one; and at Zelaya, Salamanca, and Santiago further N., in average years, from thirty-five to forty are produced. Rye and barley are raised at higher elevations than wheat, as they are less liable to be injured by cold. The potato is much cultivated in Mexico. It is not an indigenous plant, but was introduced from the mountainous parts of Peru at a very early period after the conquest of that country by the Spaniards. It grows to a large size, some of those found by Humboldt having measured from 12 to 13 inches in circumference. The banana, which flourishes up to the point where the mean temperature is 75° Fahr., produces more nutritious substance in a less space than any other plant. Humboldt calculates that an acre of ground planted with bananas is sufficient to support fifty men, whilst the same extent of land in wheat would barely supply the wants of three. It is propagated by cuttings, and requires no labour in cultivation, except that of cutting off the stems when the fruit is ripe, and occasionally digging round the roots. The same temperature necessary to the development of the banana produces also the *manioc* or *cassava*, which is also abundantly productive of aliment. Its cultivation requires more care than that of the banana, and in some measure resembles that of the potato: it arrives at maturity about eight months after the slips have been planted. Of the *manioc* there are two kinds, the sweet and the bitter; both are made into bread, but the consumption is not considerable. Rice is but little cultivated, and not very generally known. Before the year 1810 the cultivation of the olive was prohibited lest the interest of the mother country should thereby be injured. During the revolution, however, a great number of olive trees were planted, and at present there are several large plantations in the country. The vine was also a prohibited plant, but now flourishes in many parts. Among the other vegetable productions of Mexico are the yam, which is confined to the *tierras calientes;* the *capsicum,* which is extensively cultivated, and universally used for seasoning food; and the sarsaparilla, tomato, pine-apple, pomegranate, guava, orange, lemon, melon, pear, apple, peach, &c. One of the most valuable plants of the country is the *maguey,* a species of aloe, which is by Humboldt designated the vine of Mexico. It furnishes a spirituous liquor called *pulqué,* which is the chief beverage of all classes of the people. The *maguey* plantations are principally in the states of La Puebla, Mexico, Guanajuato, and a small portion of Valladolid. The most celebrated are those in the vicinity of Cholula, and in the Plains of Epam and in the valley of Toluca; but in general the plant is found wild in every part of Mexico. The plants in the plantations are arranged in rows, with an interval of 2 or 3 yards between each, and when arrived at maturity the leaves are from 5 to 8 feet in length, and the stem frequently attains a height of 20 or even of 30 feet. The *maguey,* however, often delays florescence for many years, when it pushes up its flowering spike with extraordinary rapidity. At the flowering season the exact time is watched when the stem of the flower is about to shoot up; the top is then cut off, and a hole scooped in the stalk for the reception of the sap, which is regularly drawn off, generally two or three times in a day. The plants are extremely productive; a vigorous one will yield as many as 150 gallons in a season of four or five months. The sap is placed in a situation to ferment, an operation which takes place in a few days, when it becomes fit to be drunk. Its taste is said to resemble that of cider, but its smell is disagreeable. A kind of brandy, called *mexical,* very much resembling whiskey, is produced by the distillation of *pulqué.* The *maguey* plant is useful in other respects; its fibres furnish the inhabitants with a thread called *pita,* and is also employed in making ropes and paper; its juice is used as a caustic application for wounds; and its prickles serve for pins and needles. The soil of Mexico is in many parts remarkably favourable to the production of sugar, which has become one of the most valuable products of the republic. A considerable quantity of rum is annually distilled from molasses. The Mexican soil has also been found well adapted for the cultivation of coffee, extensive plantations of which exist near Orizava and Cordova. The average produce of each plant is estimated at about two and a half pounds weight throughout all parts of the country where the berry is cultivated, though there are districts in Mexico in which it is said three or four pounds are yielded. The slope of the eastern Cordillera is supposed to be best adapted for coffee estates. Tobacco is a government monopoly, and grows well in a small district near Orizava and Cordova; but the best quality comes from Simojovel in the state of Chiapas, and from some districts of Oajaca. In Yucatan and Tabasco the plant is also successfully cultivated, and produces a mild and fragrant leaf, which is not included in the national monopoly. A large portion, however, of the tobacco sold in the country is contraband. Indigo was known and cultivated by the Mexicans previous to the conquest. It is found in Yucatan, Chiapas, and about Tehuantepec, in the state of Oajaca, and grows wild in some of the very warm districts in Tabasco. Cotton was among the indigenous products of Mexico at the time of its invasion, and formed almost the only clothing of the natives. The Aztecs possessed the art of spinning it to a very high degree of fineness, and of imparting to it beautiful and brilliant colours; but these arts have been lost. The hot regions are remarkably favourable to the growth of the plant, and it requires but little attention from the proprietor. The quantity of cotton produced in the whole country is estimated at about seven millions of pounds. Vanilla, yielding the highly esteemed spice of that name, grows wild along the eastern coast and in other parts of the republic. The cultivation, however, of this valuable product is left almost entirely in the hands of the Indians. Jalap, whose roots furnish a valuable medicine, is a native of Mexico, and grows plentifully in the neighbourhood of Jalapa, whence its name. The *opuntia,* or Indian fig, a species of cactus, supports here an insect from whose body the well-known cochineal is made. The female alone produces the dye; and the process of rearing is complicated, and attended with much difficulty. The plantations of the cochineal cactus are confined to the state of Oajaca. Soon after the independence of Mexico was secured, the cultivation of the mulberry tree was attempted, for the purpose of feeding silk-worms, but without success. In 1841 an association was formed for the encouragement of silk culture, and the mulberry tree was extensively introduced, but has been found to prosper only in certain localities. The state of Oajaca is said to be exceedingly well adapted for its culture. Flax and hemp have also been introduced into the country.

Trade.

The chief exports from Mexico are cochineal and the precious metals. Of the latter of these products it is estimated that the one-half is remitted to England, and that the other is divided equally between the United States and the continental states of Europe. The greater portion of the silver is shipped from Tampico, which is the nearest port for the mineral productions of Guanajuato, Zacatecas, San Luis Potosi, and the principal mining districts of Northern Mexico. Large quantities are also sent from Vera Cruz, as well as from Mazatlan, on the Pacific coast. In 1845, before the war with the United States broke out, and when the Mexican trade was in its ordinary condition, the value of the precious metals, coined and uncoined, shipped from these ports through the regular channels amounted to L.2,279,187. We have, however, no means of estimating the contraband exportation; but it may be safely said that at least one million sterling more found its way clandestinely to Europe and the United States. The value of cochineal exported is estimated at about L.200,000. The other exports are principally dyewoods, vanilla, sarsaparilla, jalap, hides, horns, and a small quantity of pepper indigo, and coffee. The imports consist chiefly of linen, cotton, woollen, and silk goods, paper, glassware, ironware, quicksilver, cocoa, wine, brandy, and gin. The aggregate value of the exports and imports does not exceed L.5,000,000. For the year ending 30th June 1850 the duties on importations amounted to L.1,090,227, and on exportations to L.125,780. The total shipping in 1850 amounted to 256,692 tons. Of the vessels that arrived at the various ports 68 belonged to Mexico, 435 to the United States, 108 to England, 69 to France, 60 to Spain, 13 to Hamburgh, and 24 to Peru.

Manufactures.

The manufactures of Mexico chiefly consist of woollen, cotton, and silk goods, glass, paper, sugar, oil, wine, and brandy. In 1850 there were in the republic 4 glass factories, 8 paper mills, 72 large cotton factories, 6 large woollen factories, and upwards of 70 machines worked by the hand in the manufacture of silk. In the cotton manufacture there were also a number of hand machines for making *rebosos* or long cotton shawls, bed-coverings, &c. The woollen manufactures likewise employ numerous small establishments in the country, where coarse cloths are made. In the larger mills fine cloths, carpets, flannels, &c., are produced. The annual value of the manufactures is estimated at about L.20,000,000. The Indians excel in working jewelry, carving, sculpture, and indeed in all the ornamental arts; they are likewise good masons, painters, and musicians. They make beautiful vases, somewhat similar in form to the Etruscan, as well as toys of all kinds, wax figures, ornamental cloths of great value, and the like.

Revenue. The revenue of the republic for the year ending 30th June 1852 amounted to L.1,683,000, and the expenditure to L.2,405,000. The public debt, which has been steadily increasing since the year 1827, amounted in 1854 to L.24,600,000, of which sum nearly a half was owing to foreign bondholders, these consisting principally of English and Americans. This wretched state of the public money is naturally owing to the long dissensions among the political parties, and the peculations of many of their leaders. The armed force is fixed by law at 26,353 men in the regular service, and 64,946 militia in actual service; but in 1855 not more than half of these were organized. The navy consists only of 9 small vessels, having in all 35 guns, and manned by about 300 men.

Government. The government of Mexico is a representative federal republic. The legislative power is vested in a Congress consisting of a Senate and Chamber of Deputies. The Deputies are chosen every two years by the citizens of the states, in the ratio of one for every 50,000 souls, or for any fraction above 25,000. The Senate is composed of two members from each state and the federal district, while a number equal to that of all the states is elected by the Senate, Deputies, and Judges of the supreme court conjointly, the Deputies deciding the election in the case of the candidate not receiving a majority of all the votes. The executive power is vested in a president elected for four years. Judicial power resides in the supreme court of justice, and in circuit and district courts. Each state government is independent within its local jurisdiction, and, like the federal government, is composed of executive, legislative, and judicial departments.

Religion. The Roman Catholic religion was established here by the Spaniards, and is still maintained with the utmost rigour. At the time of the revolution the pope actively espoused the cause of Spain, and anathematized the revolutionists; but on the petition of the new government they were readmitted into the bosom of the Catholic Church. The constitution of 1847 declares that "the religion of the Mexican nation is and shall be perpetually the Roman Catholic Apostolic. The nation protects it by wise and just laws, and prohibits the exercise of any other whatsoever." The ecclesiastical government is under the jurisdiction of an archbishop and eleven bishops. The dioceses contain 184 prebends and 1229 parishes, with 3223 ecclesiastics; there are besides 146 monasteries, with 1130 inmates; 59 nunneries, with 3160 inmates; and 8 colleges of the Propaganda, with 238 inmates. The revenue of the church is estimated at L.4,000,000.

Education. Education is still at a very low ebb, though of late years some progress has been made. Several of the states have established primary schools, and many higher schools and private seminaries have been opened in the cities. In the city of Mexico, in 1850, there were 129 primary schools, attended by 7151 scholars. The other educational institutions are,—First, seminaries sustained and directed by the clergy; second, national colleges in the capital, sustained partly by their own funds and partly by government aid; and third, colleges and institutions in the states supported by local funds. Of the first class there are 10 distributed in the capitals of the several dioceses, and in 1850 these contained 3024 students; of the second class there are six, viz., the college of San Ildefonso, San Gregorio, and San Juan de Letran, the School of Medicine, the Military Academy, and the College of Mining; and of the third class there are 20, including six preparatory schools.

Population. The republic of Mexico comprises 21 states, 1 federal district, and 3 territories. It has 85 cities and towns, 193 villages, 4709 hamlets, 119 communities and missions, 175 *haciendas* or estates, and 6092 farms. According to the census of 1850, it contained a population of 7,661,919, and an estimate in 1854 gives it at 7,853,395, showing an increase of 191,476 persons within these years.

States.	Population in 1851.	Area in Square miles.
Chiapas,	144,070	18,680
Chihuahua	147,600	97,015
Cohahuila	75,340	56,571
Durango	162,218	48,489
Guanajuato	713,583	12,618
Guerrero	270,000	32,003
Jalisco	774,461	48,590
Mexico	973,697	19,535
Mechoacan	491,679	22,993
Nuevo-Leon	133,361	16,688
Oajaca	525,101	31,823
Puebla	580,000	13,043
Queretaro	184,161	2,445
San Luis Potosi	368,120	29,486
Sinaloa	160,000	33,721
Sonora	139,374	123,467
Tabasco	63,580	15,609
Taumaulipas	100,064	30,335
Vera Cruz	264,725	27,595
Yucatan	680,948	52,947
Zacatecas	356,024	30,507
Federal District	200,000	90
California, Lower Territory	12,000	60,662
Colima Territory	61,243	3,020
Tlaxcala Territory	80,171	1,984
Total,	7,661,520	829,916

Of the total population, it is estimated that only about 1,000,000 are pure whites, 4,000,000 Indians, and 6000 negroes; the remainder consisting of Mestizos, Zambos, Mulattoes, Quadroons, Quinteroons, and other mixed races. The whites in Mexico are divided into two classes—Creoles, or those born in the country, and Gachupines, or native Spaniards. The Spanish population in this country still forms a numerous and important body, though the Spaniard no longer holds his former rank in the social scale. The Creole or native Mexican is commonly proud, indolent, and often vicious. An aristocratic feeling, founded on their complexion, which gives them distinction, prevents them from pursuing those kinds of labour which are deemed degrading to gentlemen. The consequence is, that their poverty is often even greater than that of the Indians; whilst from indolence, added to pride, they are prevented from following any employment beyond that of the gaming-table, or becoming the flatterers of the richer members of their own class. Throughout Mexico there is a universal predisposition to dependence upon others, or a blind reliance upon chance. The Indians form the next class of the Mexican population. They are the unmixed descendants of the aboriginal inhabitants, and consist of various tribes, resembling each other in colour, and in some general characteristics which seem to announce a common origin, although differing entirely in language, manners, and dress. No less than twenty languages are known to be spoken in the Mexican territory, and many of these are not dialects which may be traced to a common root, but differ as much as the languages of Sclavonic and Teutonic origin in Europe. Some possess letters which do not exist in others, and in most there is a difference of sound which strikes even the most unpractised ear. In colour the Indians of Mexico are darker than those of South America, although they live in a climate of lower temperature. They have more beard and more hair on other parts of their body than those of the southern continent, while almost all are free from personal deformity. The different tribes are scattered over the greater part of the country, and are mostly cultivators of the soil. A number of them, however, find employment in the mines; some are engaged in the manufacture of certain elegant fabrics of wool and cotton; and some in the formation of articles for domestic use. The Indian is remarkable for his patient endurance of fatigue and pain, and is exceedingly tenacious of old customs. After three centuries of constant intercourse with Europeans, he still keeps aloof from the foreigner, and continues to live in his native village. He speaks his hereditary language, delights in his old pastimes, and, according to the report of reliable travellers, occasionally worships in private his ancestral idols. Though the Mexican laws prohibit slavery, yet upon the plantations the Indians are in reality slaves. The tenacity with which he adheres to old habits and customs, and the strong attachment which he manifests for the place of his birth, render migration to another state or district never a voluntary act on his part. So helpless is the Indian, if placed beyond the limits of his habitual neighbourhood or accustomed haunts, that he feels himself perfectly lost and miserable if compelled to change either his residence or occupation. The Mexican planter can inflict no greater punishment on his Indian serf than to expel him from the estates on which he and his ancestors have worked from time immemorial. The Indian is also frequently mortgaged to the landed proprietor. The extravagant and licentious outbursts in which he occasionally indulges bring him under pecuniary obligations, leading him to sell himself for a number of years, or even for life, to the landholder; and this condition the latter is ever ready and willing to bring about.

The middle races have, in process of time, become a very important part of the population of Mexico. In a country where rank depends more on the complexion than on those endowments which in other countries confer distinction, it is not surprising that almost every shade has its limits defined by terms which, though apparently only expressing the colour, do in reality signify the rank of the individual. The son of a white, whether Creole or European, by an Indian female, is called *Mestizo.* His colour is almost a pure white, and his skin is of a peculiar transparency. The small hands and feet, and a certain obliquity of the eyes, are more frequent indications of the admixture of Indian blood than the nature of the hair. If a Mestizo marry a white man, the next generation scarcely differs in anything from the European race. They are, however, generally accounted of a more mild character than the Mulattoes descended from whites and Negresses, who are distinguished by the violence of their passions, and the singular volubility of their tongues. The issue of Negroes by Indian females bear in Mexico the singular name of *Chinos*, or Chinese in common language, although by law they are denominated Zambos. The term Zambo, however, is generally applied to the descendants of a Negro and a female Mulatto, or of a Negro and a female Chinese. Another gradation, called *Zambo prieto*, or blackish Zambo, is the offspring of a Negro and female Zambo. From the union of a white man and a Mulatto woman the class of Quadroons is derived. When a female Quadroon marries a white man, the children are denominated Quinteroons. The issue of a white man by a female Quinteroon is considered a white. Next to the pure Indians the Mestizos are the most numerous caste. It is, however, impossible to ascertain the exact proportion which they bear to the whole population, many of them being included amongst the pure whites. The proportion of the other mixed breeds to the whole population is equally uncertain.

It was the policy of Spain to foster a spirit of rivalry between the different classes of inhabitants, by creating little imaginary shades of superiority amongst them, which prevented any two from having a common interest. Whiteness of skin was the patent of nobility; and even the Creole, whom the Spaniard despised, looked with the contempt of a European upon the rest of his countrymen. The revolution, however, put an end to castes, the differences of which were all swallowed up in the grand distinction of Americans and Europeans. The Creoles were compelled to court the allegiance of the mixed classes, without whom they could make no effectual head against the Spaniards. Many of the most distinguished characters of the revolutionary war belonged to the mixed breeds; and under the system now established, all are equally entitled to the rights of citizenship, and equally capable of holding the highest dignities of the state. There is neither a pure African population nor a slave in the republic of Mexico.

Antiquities and ancient inhabitants

Of the ancient inhabitants of Mexico some very interesting monuments remain. The work of Humboldt on New Spain first excited the curiosity of Europeans, and rescued the antiquities of Mexico from the oblivion to which they had so long been consigned; but it was not until recently, that their value as works of art, and as indications of a considerable advance in civilization, was fully appreciated. Pyramids having even a larger base, and being otherwise scarcely inferior in magnitude to those of Egypt, are found in many parts of Mexico. Amongst the most celebrated is that of Cholula, the base of which is 1423 feet on each side, and the height 177 feet. It consists of eight graduated square towers, each rising above the other, and terminating in a species of sanctuary. Here vestiges of noble sculpture are visible, as well as at Otumba, Oajaca, Mitlan, Tlascola, and Palenque. The ruins of the latter, in particular, have attracted a considerable degree of attention, and are worthy of description. They extend, says Colonel Galindo, of whose description we shall avail ourselves, for more than 20 miles along the summit of the ridge which separates the country of the wild Maya Indians from the state of Chiapas, and must anciently have embraced a city and its suburbs. The principal buildings are erected on the most prominent heights; and several of them, if not all, have been provided with stone stairs. The principal edifice, which has been sometimes styled the palace, is built in several squares; but the main halls or galleries run in a direction from the N.N.E. to the S.S.W.; and this position has been observed in all the edifices hitherto examined, be their situation what it may. The houses have all been substantially built of stone, cemented with mortar; but symmetry has been little studied in their construction, it is supposed less from ignorance than from design. Other ruins of considerable magnitude, and distinguished by numerous sculptures, are found upon the neighbouring hills. In the vicinity there is one building in particular, apparently a religious edifice, which deserves notice. Two galleries constitute its foundation; the front one occupying its whole length, whilst the back one is divided into three compartments. Of these, the eastern has the appearance of a dungeon; the western is a small room with a chapel ornamented with elegant relievos. These consist of representations of the human figure, in various attitudes, and adorned generally with boughs and feathers. There are other very interesting ruins in this part of Mexico, but they have not as yet been sufficiently described.

The Mountain of Tezcoca is nearly covered with ruins of ancient buildings. At Mitlan there are the remains of a large palace, the architecture of which possesses a stately grandeur, and melancholy beauty of a peculiar character. The roof of the portico is supported by plain cylindrical columns, and the façade of the palace is covered with a beautiful matwork, or basket scroll, such as is found in Egyptian sepulchral chambers. Many of the statues found at Otumba, Mitlan, Jochichalo, and the magnificent flower-temple of Oajaca, are sculptured in a purely classical style; whilst vases rivalling those of Egypt and Etruria have been discovered in sepulchral excavations. Roads are to be met with, not only in the vicinity of great cities, but at a vast distance from them, artificially constructed, like the Roman military roads, of large squared blocks of stone. These roads present a continued level, and may be called viaducts, in contradistinction to aqueducts, which were also constructed by the ancient inhabitants of Mexico. Where they traverse acclivities, they are parapeted; and the indications may still be observed, both of regular posting stations at certain intervals, and of the regular division of the distances. upon the principle of the milestones of our turnpike roads. Bridges constructed of the same durable materials, and thrown across torrents, are also to be found. In these bridges there is occasionally an approximation to the principle of the arch and keystone; but in general they only display the primitive and obvious form of architraves of stone superimposed on two or more piers of the same massy character and durable materials. Every feature of these structures is at once singular, ingenious, and colossal.

With regard to the period at which these remarkable edifices were constructed, and the people to whom the labour is to be attributed, the learned are as yet not agreed. One point, however, seems pretty generally admitted, viz., that their erection must be traced to a race who inhabited the country prior to the invasion of the Mexicans, and who had attained to a considerable degree of civilization. An attempt has been made to prove that this people lived at a time prior even to the Toltecans, who preceded the Mexicans by 600 years; and a close analogy between the antiquities of Mexico and those of Egypt has been shown to exist. The hypothesis advanced regarding the people is, that they were a branch of the Anakim or Cyclopean family of Syria, the shepherd kings of Egypt, the Oscans of Etruria, and the Pelasgians of Greece, the Titans or giants of classical romance, and who are recorded to have been severally expelled from Egypt and Syria.

In reference to these questions, an able writer observes:—"The first and strongest conviction which will flash on the mind of every ripe antiquarian, whilst surveying the long series of Mexican and Toltecan monuments, preserved in the various works to which we have alluded, is the similarity which the ancient monuments of New Spain bear to the monumental records of ancient Egypt. Whilst surveying them, the glance falls with familiar recognition on similar graduated pyramids; on similar marks of the same primeval Ophite worship; on vestiges of the same triune and solar deity; on planispheres and temples, which, though characterized by some distinctions entirely American, are not less worthy of the notice of the Egyptian antiquarian; on relics of palaces at once noble in their architecture and beautiful in their proportions and decorations; on monuments sepulchral, domestic, religious, or warlike, which deserve the designation of Cyclopean as much as any that are now extant in Italy or Greece; on idols and sculptures, some of rude and some of finished workmanship, exhibiting different eras of civilization, and often presenting the most striking analogy in posture and gesture to the monumental style of sculpture, and of statuary pre-eminently called Egyptian. Lastly, the eye of the antiquarian cannot fail to be both attracted and fixed by evidences of the existence of two great branches of the hieroglyphical language; both having striking affinities with the Egyptian, and yet distinguished from it by characteristics perfectly American. One is the picture-writing peculiar to the Mexicans, and which displays several striking traits of assimilation to the anaglyphs, and the historical tablets of the Egyptian temples. The second is a pure hieroglyphical language, to which little attention has been hitherto paid, which appears to have been peculiar to the Toltecans, or some still more ancient nation, that preceded the Mexicans, which was as complete as the Egyptian in its double constituency of a symbolic and phonetic alphabet, and which, as far as we can judge, appears to have rivalled the Egyptian in its completeness, whilst, in some respects, it excelled it in its regularity and beauty."

"The pyramid of Cholulas," says the same writer, "exhibits a most singular identity with the model of the temple of Belus, described by Herodotus, and which, by many scholars, has been considered to be the Scriptural tower of Babel. But in the internal economy of the pyramids, the analogy between those of Egypt and Mexico is still more remarkable. In both, descending galleries, at a particular astronomical angle of declination, lead to central chambers, either for the purpose of mystery or sepulture. Amongst other marks of architectural identity may be mentioned those traced amongst the ruins of Palenque, where the well-known Cyclopean arch, consisting of receding steps of stone in a triangular form, is seen, and where a rectangular square is surrounded by cloisters built in this manner, and lighted by windows bearing the exact form of the Egyptian face. With regard to the personal characteristics and costume, the sculptures bring to light a people of a very remarkable appearance. Their physiognomy is unlike that of any of the various families of mankind that at present inhabit the globe, or have been rendered familiar to us by ancient sculptures. Their receding forehead, their low facial angle, and the conical form of their heads, is quite unique; and the large long nose, the facial line receding in the same singular manner from the base of the nostrils to the termination of the chin, grotesquely broken off by an unsightly protrusion of the under lip, present a physiognomical outline revolting to the European standard of beauty. The costume shows some striking analogies with that of the Egyptians; but there are at the same time differences from it as remarkable. The Egyptian apron, for instance, was different. It was generally of striped cotton, and folded in a peculiar manner; a portion of it forming a girdle, and passing between the legs, resembling a similar article of dress worn by the East Indians at the present day. But the Toltecan apron resembles the Roman military apron or the Scotch philabeg. It descends from the waist and covers the thigh down to the knee; it is, however, distinguished by one Egyptian appendage, namely, by the mimic tail of an animal, which appears to have adorned the Toltecan hero as it adorned the Egyptian demigod. The apron is supported by a baldric, which descends from the right shoulder to the left side, and joins the girdle at the waist. The dress of the military and superior class of Egypt is not to be found in the Toltecan costume, but the following strong resemblances exist:—The breast-plate and collar of the Toltecans were sometimes decorated with a symbol of the sun; the armlets, bracelets, and anklets, are strikingly analogous to those of the Egyptian. The legs of the Toltecan heroes, however, are invested with sandals, some of them reaching above the ankle, others like greaves, covering the leg to the knee; whilst others in every respect resemble the Highland sandal. All these parts of dress would appear to have been richly ornamented; and the whole dress, it is said, may be safely described as at once gorgeous and elegant, and in these respects nowise inferior to the Egyptian. The head-dresses, however, are in general extravagantly grotesque, without regularity or taste, although, like the Egyptian, constructed out of certain combinations of symbols."

With respect to the religion and religious rites of this ancient race, a striking analogy with those of Egypt has likewise been traced. The gods of the Toltecans appear sculptured, as usual in bas-relief, in the dark inner rooms of temples. He who would appear to be the chief-god is portrayed on the inner wall of the adytum of one of the sanctuaries belonging to the great temple of Palenque, and is worshipped symbolically under other forms and in other localities. He is supposed to be identical with the Osiris of Egypt and the Adonis of Syria, or the well-known classical combination of both divinities, the ancient god *Adoni-Siris*. The manner in which he is enthroned, the cushion on which he reposes, the cap, the symbols, and various appurtenances, show an analogy with the Egyptian deity. But there is a column affixed to the cap which is not found on any Egyptian head-dress; it was, however, an unquestionable symbol of Osiris. "Various characteristics of the worship of Osiris and Adonis are complete in the sculptured tablets of Mexico. A priestess kneels before the Toltecan god in the attitude of adoration, and offers him a pot of flowers, not the mint offered to Osiris, but the blood-stained hand-plant or *manitas*, which all the monuments attest was anciently held sacred throughout Mexico. On the sculptured tablet over the head of the divinity appear, precisely in the Egyptian fashion, the phonetic characters of his name, in an oblong square, which in Egypt was devoted to the names of gods. Of the phonetic or symbolic character, however, nothing as yet is known. The same divinity is represented on one of the walls at Palenque, not in a human, but in an animal form. Instead of the hawk of Egypt, however, the Toltecans chose as their sacred bird the rainbow-coloured pheasant of Central America, which is perched on the Toltecan cross, resembling the Christian, and with its lower extremity terminating in a heart-formed spade. The subject of the sculpture shows the simplicity of the worship. Two Toltecan heroes, chiefs, or priests, stand beside the sacred bird; one of them supports an infant in his arms, probably for baptism, which was a rite practised by the votaries of Adonis, and at other places there are indications of a similar ceremony."

Of the temples we have already given a cursory notice. Their architecture has a theological character like that of Egypt and of Greece; and although their forms are peculiar to the country, the original type of them is extant in Syria, Palestine, and Judæa. Like those of the Egyptians, they are all distinguished by architectural peculiarities, exclusively appertaining to the people by whom they were erected. A high-place of three successive terraces or steps generally constitutes the platform of the temple. The terraces are distinguished by that sloping form which the Egyptian architects peculiarly affected, and they are generally constructed of large blocks of stone, covered with stucco equally hard and durable. On the top of the high-place was an oblong rectangular court; and in the centre of this court stood the temple, divided, like the rock temples of Nubia, into three dark rooms built of stone, and having an ark or barn-shaped roof. The innermost of these rooms constitutes the sanctuary. The apartments are occasionally decorated with painted sculptures. Sometimes the staircase ascends the high-place in front, traversing the curvilinear terraces in a straight line to the door of the temple. Occasional variety was given to the square form of the area, and to the triple form of the terraces, by staircases ascending to the sanctuary from each of the cardinal points. The high-place has sometimes a circular instead of a square ground-plan, and in that case, it may remind antiquarians of the well-known *Tepes*, or high-places of Syria, which is a presumptive proof of the Syrian origin of these structures.

The writer already quoted thus speaks of Palenque:—"It may be appropriately termed an ecclesiastical city rather than a temple. It seems to be the locality of the chief cathedral church of the Toltecan religion. Within its vast precincts there appear to be contained a pyramidal tower; various sanctuaries; sepulchres; a small and large quadrangular court, one surrounded, as we have said, by cloisters; subterranean initiatory galleries beneath; oracles, courts of justice, high-places, and cells or dwellings for the various orders of the priests. The whole combination of the buildings is encircled by a quadrilateral pilastered portico, embracing a quadrangular area, and resting on a terraced platform. This platform externally exhibits the same architectural model, which we have described as characterizing the single temples. It is composed of three graduated stucco terraces, sloping inwards, at an angle of about seventy degrees, in the form of a truncated pyramid. Four central staircases, one facing each of the cardinal points, ascend these terraces in the middle of each lateral façade of the quadrangle; and four gates, fronting the same cardinal points, conduct from the top of each staircase into the body of the building, or into the great court. The great entrance, through a pilastered gateway, fronts the east; and descends by a second flight of steps into the cloistered court. On the various pilasters of the upper terrace are the metopes, with the singular sculptures we have described. On descending the second staircase into the cloistered court, on one side appears the triple pyramidal towers, which may be inferred, from the curious distribution of little cells which surround the central room of each storey, to have been employed as a place of royal or private sepulture. On another side of the same cloistered court is the detached temple of the chief god, to whom the whole religious building appears to have been devoted, whom we have described as bearing all the characteristics of the Syrian god Adoni-Siris, and who appears to have been the great and only god of the nations who worshipped in this temple. Beneath the cloisters, entered by well-staircases from above, are what we believe to be the initiatory galleries. These opened into rooms, one of which has a stone couch in it, and others are distinguished by unintelligible apparatus carved in stone. The only symbol described as found within these sacred haunts is, however, perfectly Asiatic and perfectly intelligible; we mean two contending serpents. The remnant of an altar, or high-place, occupies the centre of the cloistered quadrangle. The rest of the edifice is taken up with courts, palaces, detached temples, open divans, baths, and streets of priestly cells or houses in a greater or less degree of dilapidation."

It appears that the creed of this ancient people was a form of deism, which permitted some varieties of symbolic representation. From the few records of their religious rites which have come down to us, and which are principally derived from the extraordinary rolls of American papyrus, formed of the prepared fibres of the *maguey*, on which their beautiful hieroglyphical system is preserved, we learn that they were as simple as their creed. No human or even animal sacrifices appear to have been offered up to the presiding divinity of their temples; nothing, indeed, but fruits and flowers. Such a religious system was therefore quite different from the hideous idols and sanguinary sacrifices which were in use amongst the Mexican people.

IV.—POLITICAL DIVISIONS.

Mexico. The republic of Mexico, as has already been stated, is divided into twenty-one states, a federal district, and three territories, each of which we shall now proceed to give a short account of. Mexico, the most populous of the whole, and which also contains the metropolitan city and the federal district, extends from 18. 30. to 21. 57. of N. Lat., and from 98. to 101. W. Long., and includes an area of about 19,535 square miles. It is bounded on the W. by the state of Michoacan, S.W. by the state of Guerrero, N. by that of Queretaro, E. by Puebla, and N.E. by Vera Cruz. This state is situated on the high lands of the interior, and its surface is almost entirely mountainous. Only one of its peaks, however, attains the height of perpetual snow, namely, that of Toluca, upwards of 15,000 feet above sea-level. The climate is necessarily cool and salubrious. This upland region embraces a large proportion of valuable mines. To the N. and N.E. of the central valley of the state are the great silver-mining districts of Real del Monte, Moran, and Atotonilco el Chico. Iron, lead, and carbonate of soda are also found in the state. But rich as the mines

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of this country are, the fertility of its soil is even more remarkable, producing every variety of plant with rapidity, and in the greatest luxuriance. The most valuable land, however, is what is called the Valley of Mexico, a splendid region, variegated with extensive lakes, and surrounded by high volcanic peaks. Its general figure is an oval of about 200 miles in circumference, and forms the very centre of the great table-land of Anahuac, elevated from 6000 to 8000 feet above the level of the ocean.

The most interesting object in the Valley of Mexico is the vast system of drainage by which the capital is protected against the periodical inundations of the Lake of Tezcoco, which, during the first two centuries after the conquest, threatened it repeatedly with destruction. The Valley of Mexico serves as a receptacle for the water which filters from every part of the lofty ridge of mountains by which it is environed. Only one stream issues from it, whilst it receives the waters of several rivers, which, accumulating in the immense basin, form respectively the great lakes Tezcoco, Zumpango, San Cristobal, Chalco, and Jochimilco. The city being situated on a lower level than some of these sheets of water, particularly that called Zumpango, during the rainy season they occasionally burst the dykes which inclose them, and rush towards the capital, filling the lower parts of the city with water. A rapid succession of misfortunes arising from these inundations compelled the Spanish government to adopt measures for averting the danger. Hydraulic works of immense magnitude were begun in 1607; canals were cut; and other artificial means were adopted to convey the waters of the lakes in another direction. The *desague*, or great canal which was constructed to carry off the waters of the Lake of Zumpango, is of stupendous dimensions, being 12 miles in length, 300 feet in breadth, 150 in depth, and for a distance of 1000 yards cut through the solid rock. During the revolution these works were much neglected; nor have they yet been properly finished or put in a good state of repair. In the Lake of Chalco there are a number of *chinampas*, or what have sometimes been called floating gardens. They are artificial islands, about 50 or 60 yards long, and not more than 4 or 5 wide, on which the finest culinary vegetables, fruits, and flowers are raised, and from which the markets of the capital are amply supplied.

In the centre of this valley stands Mexico City, capital of the republic and of the federal district. Tenochtitlan, the ancient capital of the Aztecs, was built on several islands in the Lake of Tezcoco, and connected with the land by four long causeways; but the drainage of the marshes and the removal of the forests, combined with other causes, have produced a great diminution in the water of the lake; so that the modern city of Mexico, which is believed to occupy the same site, is removed from its shores by a distance of 2½ miles, although in the rainy season of the year the easterly winds occasionally cause the water to overflow the outskirts of the city, which is protected from such incursions by dykes. The city is generally reputed by travellers to be the most beautiful on the American continent, and never fails to excite the admiration of those who view it for the first time. It is regularly built in the form of a square, with its streets, which are both long and wide, intersecting each other at right angles. They are well paved, but not lighted, and often very imperfectly cleaned, though the town is well supplied with water brought by splendid aqueducts from the neighbouring hills. The houses, built of hewn stone, have a massive and sometimes rather forbidding appearance. They generally inclose an open court, round which the different apartments are situated, the entrance being by an iron gate in front. Opposite to this is placed the staircase by which access is gained to the upper storeys and to the roof, which is flat, surrounded by iron balustrades, and sometimes ornamented with bronze and mosaic work of glazed porcelain. The style of architecture in the city resembles that of southern Europe; and the public buildings are in many instances very imposing in their appearance. Mexico contains several squares, the principal of which, the Plaza Mayor, which occupies the centre of the town, is of very large extent, and is surrounded by the chief public buildings. The centre of this square was formerly occupied by a large statue in bronze of Charles IV.; but this has been removed to the quadrangle of the university. On the north side of the Plaza Mayor is the cathedral, which stands on the alleged site of the ancient *teocalli*, or temple of the Aztec war god Mexitli, from whom the city derives its name. The cathedral is 500 feet in length and 420 in breadth; and though the style is irregular, and not in strict accordance with any architectural order, its appearance, especially in the interior, is very imposing. The front is profusely ornamented with carving; and is partly in an inferior Gothic style and partly in the Italian. There are also two lofty towers, adorned with pilasters and statues. In the outside wall of the building is the *Kellenda*, a circular stone of basaltic porphyry, covered with hieroglyphical representations of the months of the year, which is supposed to have been used by the Aztecs as a calendar. The interior is very richly decorated with carved work, columns, statues, shrines, pictures, &c., but these are distinguished rather for their rich and gorgeous character than for elegance or beauty. The high altar is laden with a vast number of candlesticks, crosses, and religious reliques of gold and silver, and surmounted by an image of the Virgin so richly adorned with jewels as to be valued at more than half a million sterling. From the sacristy, extending round the choir for about two hundred feet, runs a railing, between four and five feet high, composed of the precious metals, very slightly alloyed with copper. It is said to be worth its weight in silver. The east side of the great square is occupied by the National Palace or Government House, formerly the residence of the viceroy, but now that of the president. It is a large quadrangular building with four interior courts, and contains, besides the apartments of the president, the public offices, the Senate-house, the two Chambers of Deputies, the mint, two barracks, two prisons, several shops, and a botanic garden. This edifice is believed to occupy the site of the ancient palace of Axayacatl, which was allotted by Montezuma to Cortez as his residence. The remaining sides of the square are formed by private dwellings, with the exception of the south-eastern corner, which is occupied by the City Hall, part of which is used as an exchange. The university of Mexico is situated near the square, and contains the National Museum; opposite which is the extensive market constructed in 1842. The Mineria, or School of Mines, in which occasional lectures are given, is an elegant building situated a little to the west of the square. These institutions, however, as well as the Academy of Fine Arts and the public library, have been very much neglected since the revolution, and are now in a declining condition. The Acordada, or public prison, is an edifice of great size and strength, capable of containing 1200 prisoners; and there is a large and well-built artillery barracks, which was formerly used as an hospital. Besides the cathedral, Mexico is said to contain between fifty and sixty churches and convents, most of them in a mixed style of architecture, and remarkable chiefly for the richness of their ornaments. The church of San Domingo is light and elegant, with a spire and dome; and near it is situated the building formerly occupied by the Inquisition, which was abolished here in 1822. The largest and most wealthy convents are those of the Franciscans and of the Dominicans; and these, along with the convents of St Augustine and La Merced, are the most remarkable edifices of that sort in Mexico. There is also a handsome theatre, and a

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large circular arena for the exhibition of bull-fights, called the Plaza de Toros, which has accommodation for 2000 or 3000 spectators. At the west end of the town there is a park called the Alameda, which is a great place of public resort, and has an area of 10 or 12 acres, laid out in walks and labyrinths, and adorned with numerous fine trees. There are also two other promenades or *paseos*, as they are called, one on the E. and the other on the W. of the city. These consist of the roads leading from the town, which are raised several feet above the surrounding country, and lined with double rows of fine trees, thus affording delightful promenades, which are frequented by great multitudes of the inhabitants. The one which leads to the east, called the Paseo de la Viga, skirts the Lake Chalco Canal, which adds much to the appearance of the promenade. In the city also there are several covered colonnades or arcades, which form a favourite place of resort in the evening, and are often crowded long after the other promenades are deserted. The city is supplied with water by means of two aqueducts; one of which, 11,155 yards in length, extends from Santa Fé to the Alameda, and is carried for one-third of its course on arches of stone and brick. This aqueduct supplies the city with water of an excellent quality; while the suburbs to the S. are supplied by that of Chapoltepec, which is 3608 yards in length. The manufactures carried on in Mexico are remarkable neither for quantity nor for quality; the most important being those of tobacco and plate, together with that of gold and silver lace, which is well made, and sold at a very cheap rate. Jewelry, upholstery, coachmaking, as well as the manufacture of soap, and woollen and cotton stuffs, are also carried on in Mexico; but the demand for manufactured goods is chiefly supplied by the importation from Europe of articles of all sorts, and of silks from China. These constitute the staple of the import trade; and the products of the mines are the chief articles of export; indeed, the commercial as well as the manufacturing industry of Mexico is very small, and the city derives its importance almost exclusively from its being the capital of the confederation and the residence of the president. The markets are supplied with provisions by small boats, which bring them over the Lake of Tezcoco, or over the Lake and through the Canal of Chalco.

The inhabitants of Mexico City are of several different races and characters. They consist of Creoles or descendants of the Spaniards, of Mestizos or half-castes, of copper-coloured natives, of Mulattoes, and of Europeans. Of the higher classes, many have acquired considerable wealth; but the great bulk of the people are very poor; and the lower orders, in their idleness and dirty habits, as well as in their general character, have a striking resemblance to the lazzaroni of Naples. Pop. (1850) estimated at 170,000.

There are a number of other towns in the state of Mexico. Acapulco, on the S.W. coast, was once celebrated for its wealth, and is described as a very fine seaport. It was from this place that the richly-freighted Spanish galleons took their departure to distribute the spoils of the Western over the Eastern Hemisphere. It has since sunk into comparative insignificance, and now contains only about 4000 inhabitants. Zacatula is likewise a good port on the same shore, but has little trade. Toluca, the nominal capital, is a considerable town, situated at the foot of two steep barren hills, about 27 miles S.W. from the federal metropolis. It has considerable soap and candle factories, and is noted for its hams and sausages. Tezcoco, on the eastern shore of the lake of that name, 12 miles from Mexico, is now almost desolate, and only interesting for its historical associations and ancient remains. Amongst other small towns may be mentioned Otumba, once large and flourishing, but now a mere village; Lerma, which is surrounded by an extensive morass, traversed by fine raised causeways; Chalco, a pretty large town, situated in a lake of the same name, about 20 miles S.E. of the metropolis; San Augustin, at which a great annual fair is held, frequented by vast multitudes from Mexico; Tacubaya, a village about four miles from the gates of the capital, and formerly the country residence of the Bishop of Mexico; Pachuca and Cuyoacan. Besides these places there are a number of farm-hamlets, of which Chapingo is considered as one of the finest specimens in Mexico. It is distant about a league from Tezcoco; and the lands around it are exceedingly rich and well irrigated. The buildings erected to receive the grain are on a magnificent scale; while the vicinity of the capital, in affording a ready market for the crops, renders the estate one of great value. About 60 miles from the metropolis is Cuernavaca, a place of no importance in itself, but deriving interest from the richness of the surrounding district. In the neighbouring valley of Cuautla stands the town of Cuautla Amilpas, where Morelos made so noble a stand against the royal army. In the neighbourhood of Cuernavaca is the village of Acapantzingo, entirely inhabited by Indians, who have ever kept themselves apart from the Spanish population.

Queretaro.

QUERETARO.—To the N.W. of Mexico is the small state of Queretaro, the territories of which were formerly comprehended in the neighbouring intendancies of Mexico, La Puebla, and Guanajuato. They are now divided into the six *partidos* or districts of Amealco, Cadereyta, San Juan del Rio, San Pedro Toliman, Queretaro, and Jalpam. Queretaro lies entirely on the central plateau of the Cordillera, and is intersected by numerous mountain spurs and elevated hills, some of which are entirely bare, while others are covered with forests of various kinds of wood. The agricultural portions of the state are chiefly confined to the valleys, in which the soil is frequently of great fertility. The chief mining district, and the only one of any note in the state, is that of El Doctor, in the district of Cadereyta. The inhabitants, with the exception of those of the capital, are mostly employed in agriculture. The wool of the sheep is highly prized; but agriculture here is not so important a speculation as it is in other parts of the republic. Queretaro, the capital, is a finely-situated and well-built town, with about 50,000 inhabitants. It contains some fine churches and convents, particularly that of Santa Clara, which is an immense building, said to resemble a little town in the interior, being regularly laid out in streets and plazas. This place has quite the air of a manufacturing town. More than half the houses contain shops; and the population is engaged either in small trades, or in the wool manufactories, which are very extensive. The town is well supplied with water by means of an aqueduct about 6 miles in length, for 2 of which it is elevated on arches 90 feet high. The only other towns of importance are San Juan del Rio, San Pedro de la Cañada, and Cadereyta.

Guanajuato.

GUANAJUATO.—To the westward of Queretaro is Guanajuato, the smallest state in the republic, with the exception of Queretaro, but at the same time having proportionally the greatest number of inhabitants. Large portions of the soil are of great fertility, especially the magnificent plains of the Bajio, in the southern part of the state, which extends for more than 100 miles from Apasco to beyond Leon; and in the N., where the splendid plains or *llanos* of San Felipe spread far and wide. The only river of any size is the Lerma or Tolotlan; and the only lake is that of Yurirapundaro, about twelve miles in length by two in width. The state contains three cities, four market-towns, and thirty-seven villages. The manufactures of wool and cotton, which formerly abounded in many of the towns, have recently much declined. Mining and agriculture now constitute the chief sources of wealth. The mineral productions are very valuable. The town of Guanajuato, in the vicinity of which the principal mines are situated, contains numerous splendid memorials of the former wealth of its inhabitants. Many of the private dwellings are magnificent, as are the churches, chapels, and other religious edifices. The town contains a cathedral, two chapels, several monasteries and nunneries, a college, a theatre, barrack, mint, university, gymnasium, and about 50,000 inhabitants. Celaya City is a considerable town, containing about 15,000 inhabitants. The town of Irapuato has a population of about 16,000 souls, and contains some fine public buildings, particularly the nunnery called De la Enseñanza. There are a few cotton-spinners and weavers, but the bulk of its population consists of agriculturists, who reside in the town, and have estates in the vicinity. Salamanca is likewise a considerable place, situated in a rich part of the country, and has a population of about 15,000. San Miguel Allende, formerly San Miguel el Grande, is a pleasantly situated town on the river De la Laja, and contains about 5000 inhabitants.

Jalisco.

JALISCO or GUADALAJARA.—To the westward of Guanajuato, and stretching along the Pacific for 480 miles, is the large state of Jalisco, formerly Guadalajara. It is divided into eight districts, viz., Guadalajara, Lagos, La Barca, Sayula, Etzatlan, Autlan, Tepic, and Colotlan; and these, again, are subdivided into 26 departments, containing in all 318 pueblos, 387 haciendas, and 2534 ranchos. The greater part of Jalisco lies on the western slope of the Cordillera; and its table-lands, which resemble those of the great plateau of Mexico, are somewhat broken up by mountain ranges. The upper regions are consequently comparatively sterile, while the low lands are rich and fruitful. The sierras of Bajona, in the N.E. of the state, are its most remarkable mountain ranges. The principal stream is the Rio Grande de Santiago; but during the six months of the dry season its waters are either extremely shallow or disappear altogether. The Lake of Chapala, about 45 miles from the city of Guadalajara, is about 100 miles in length by 15 to 25 in breadth. The city of Guadalajara, capital of Jalisco, is situated upon an extensive plain about 450 miles from Mexico. It is built with great regularity, the streets running at right angles, being well paved, and having raised pathways on each side. The houses, with the exception of those in the suburbs, are finely built. There are fourteen squares, twelve fountains, and a number of convents and churches, the principal of which, the cathedral, is still a magnificent building, although it suffered severely in an earthquake which occurred in 1818. The Alameda, or public walk, is very prettily laid out, with a fountain in the centre, and a stream of water all round. Within the town the Portales de Comercio, erected on every side of those immense squares of houses, are the principal rendezvous; as, besides a number of handsome shops well provided with European and East Indian manufactures, they contain a number of stalls covered with a great variety of domestic productions. Considerable quantities of shawls of striped calico were formerly made here; but these home manufactures have been superseded by importations from the United States. Jalisco derives little benefit from its foreign trade, San Blas, the only seaport which it possesses, being nearly abandoned. Foreign goods are introduced overland from San Luis or Mexico. The population of the capital amounts to about 50,000 souls. The town of San Juan de los Lagos, situated in a deep ravine upon a river of the same name, is noted for an annual fair held here, which lasts for eight days, commencing on the 5th December. The town of Tepic is, next to the capital, the finest and most populous town in the state, and has a population of about 15,000. The only mining region of any note in this state is that of Bolaños.

Mechoacan.

MECHOACAN.—The state of Mechoacan is bounded on the N. by Guanajuato, N.E. by Queretaro, S.E. by Mexico, W. by Jalisco, and S.W., for a short distance, by the Pacific. It lies chiefly on the western slope of the Cordillera, and its surface is considerably broken by mountains and valleys. The land is abundantly watered by streams and rivers, and incloses a great number of lakes. This state contains 2 cities, 3 towns, 256 pueblos, 333 haciendas, and 1356 ranchos, and is distributed into 83 parishes and 21 districts. The former riches of the state consisted almost entirely in its agricultural produce, the most ordinary manufactures being introduced from the neighbouring towns of the Bajio. But the agricultural interest is by no means in so flourishing a condition as it once was, nor are the mines remarkable either for their extent or their value. The whole western declivity of the Sierra Madre, comprehended within the province of Mechoacan, is noted for its insalubrity; and the sea-coast, as might be expected, is likewise very unhealthy. The *tierra caliente*, at the foot of the Cordillera, which is fertilized in part by the Rio Balsas, is rich in all the ordinary productions of the tropics; and even in the more elevated valleys sugar was grown to a very considerable extent before the revolution. The best sugar lands are now about 36 miles S. of Pasquaro, the ancient capital of the Indians. At the foot of the Mountain of Jorullo there are plantations of cocoa and indigo; and in several parts of the state the various productions of the table-land can be raised in abundance. The mining districts of the state are Tlalpujahua, Angangueo, and Ozumatlan. Mechoacan has been called the cradle of the revolution, from which it suffered severely.

Morelia, the capital of the state, formerly called Valladolid de Mechoacan, is delightfully situated at the height of 6300 feet above the level of the sea. It consists chiefly of one long, broad street, well paved, and kept in good order. The plaza is remarkable as having broad piazzas on three of its sides, and the fine cathedral, isolated from all other buildings, bounding it on the east. Here there is a crowded market, where the venders display their goods, as is the general custom throughout the republic, beneath the shade of rude mat umbrellas. All the houses have flat roofs, with long water-spouts projecting most incommodiously over the streets. Besides the cathedral, which is crowded with a profusion of ornaments, there are several other churches, two nunneries, and four monasteries, for all which, besides an hospital and other public edifices, the inhabitants are indebted to the munificence of the bishops of the see. The population has been estimated at 25,000.

Guerrero.

GUERRERO.—This state was created by virtue of the 4th article of the Acta de Reformas, passed in May 1847, amending the constitution of 1847. By this article it was agreed that the state of Guerrero should be formed of the districts of Acapulco, Chilupa, Tasco, and Tlapa, and the municipality of Coyucan,—the first three of which belonged to the state of Mexico, the fourth to Puebla, and the fifth to Mechoacan. The physical character and productions of this state correspond with those of the three states to which this region originally belonged. Its capital is Tixtla, and contains about 4000 inhabitants.

La Puebla.

LA PUEBLA.—The state of La Puebla, which is situated to the E. of that of Mexico, and stretches nearly across the continent, is divided into 25 districts, and possesses 5 cities and towns, 126 parishes, 590 villages, 412 haciendas, and 875 ranchos or farms. The territory of the state extends beyond the western ridge of the Sierra Madre, and down to the shores of the Pacific; consequently it produces in abundance the fruits either of the *tierras calientes*, or those common to the rest of the table-land. There are, however, no mines which uniformly create a home market; and as the foreign trade is comparatively of but little importance, the agricultural interest is in a depressed condition. Manufactures of wool and cotton are carried on to some extent in the state. Some parts of the state, particularly the plains of Apam, are remarkable for their fertility. La Puebla contains Popocatepetl, the loftiest mountain in North America, situated near its S.W. boundary. The capital and largest city of this state is Puebla de los Angelos, the seat of the richest bishopric in the country, and that of the most extensive manufactures of cotton, earthenware, and wool. Glass and soap are also made; the latter to a considerable extent. The streets, like those of Mexico, are rectangular, spacious, airy, and paved with large stones in a highly ornamental manner. In the centre of the town is a large well-paved public square surrounded by *portales*. The houses are low, but commodious, and the apartments are mostly paved with porcelain, and adorned with paintings in fresco. There are a great number of churches and convents, religious colleges, and a magnificent cathedral, richly ornamented, and held in high veneration, in consequence of a tradition that it owes its origin to divine interference. The principal other towns in the state are Cholula, Atlixco, Guauchinango, Tehuacan de las Granadas, Tepeaca, and Huajocingo. La Puebla City contains about 71,600 inhabitants.

Tlascala.

Tlascala, which was declared a federal territory in 1847, has an area of about 2000 square miles, and contains 1 city, 109 villages, 18 settlements, 168 haciendas, and 94 ranchos. It is divided into 3 partidos or districts, called Tlaxco, Huamantla, and Tlascala. Its soil is of considerable fertility, and its climate mild and genial. Its productions are chiefly of a cereal character. The capital, of the same name, is situated on the Rio Atoyac or Papagallo, the only stream of importance in the territory. It is well and regularly built; and has a town-hall, bishop's palace, a tastefully-built church, and a Franciscan convent. Many relics and ruins of its former glory are still to be found in the town and vicinity. At present it contains probably not more than 5000 inhabitants.

Oajaca.

Oajaca.—Oajaca is a very fine state, the southern boundary of which extends along the coast of the Pacific Ocean a distance of about 360 miles, from La Puebla to Guatemala. Agriculture is highly favoured by the fertility of the soil and the salubrity of the climate. The Cordillera, which here forms two branches, one extending along the shores of the Pacific, the other along those of the Gulf of Mexico, incloses the beautiful and fertile region termed the Valley of Oajaca, which constitutes a great part of this state. The staple productions are,—corn, chile, agave, cotton, coffee, sugar, cocoa, vanilla, tobacco, cochineal, wax, honey, and indigo; while gold, silver, copper, quicksilver, iron, rock-salt, limestone, gypsum, &c., are found in the state. In the two mountain regions separated by the valley have dwelt two Indian races from the earliest periods, known as the Mixtecas and Zapotecas, the former of which is characterized by activity, intelligence, and industry. This state is divided into 8 departments and 23 cantons, and contains 1 city, 8 towns, 913 villages, 137 haciendas, and 235 ranchos. In ancient times this state was the seat of two independent kingdoms, viz., those of Mixteca and Zapoteca. Oajaca, the capital, called *Antequera* at the time of the conquest, is a flourishing place, although it suffered severely during the revolution. It contains about 25,000 inhabitants. The best seaport in the state is Tehuantepec. About 30 miles from the capital, on the road leading to Tehuantepec, are the remains of what antiquarians have styled the sepulchral palaces of Mitla, lying in the midst of a rocky granitic region, and surrounded by sad and sombre scenery. According to tradition, they were erected by the Zapotecas as palaces or tombs for their princes. They consist of three edifices symmetrically arranged, the principal and finest having a front of nearly 150 feet. The walls are covered with figures and ornaments. The stones that compose the building are of immense size,—one of them, above one of the principal entrances, is said to be 19 feet 4 inches long, 4 feet 10½ inches broad, and 3 feet 9 inches thick, and there are others of similar dimensions. About 90 miles N. of the capital, near the village of Quiotepec, is an eminence covered in almost every direction with remains of military works of a defensive character.

Vera Cruz.

Vera Cruz.—Vera Cruz comprises a narrow strip of land stretching along the Gulf of Mexico from the state of San Luis Potosi to that of Tabasco, a distance of about 400 miles, whilst its breadth on an average does not exceed 50 or 60 miles. The eastern part of the state is generally level, low, and sandy; but it gradually rises inland until the country is broken into an uninterrupted series of lofty mountains and beautiful valleys. The coasts are rich in rivers, streams, inlets, and lagoons, but unfortunately they are of little practical use in navigation. There are several mineral springs in the state; and at Atotonilco, near Calcahualco, in the district of Cordova, there are warm baths celebrated for their efficacy in nervous and rheumatic complaints. The state is divided into four departments, viz., Vera Cruz, Jalapa, Orizava, and Acayucam.

The productions of this state are rich and varied; the differences in its altitude render it capable of yielding fruits and grains both of the temperate and torrid zone. Tobacco, coffee, sugar, cotton, corn, barley, wheat, jalap, sarsaparilla, vanilla, oranges, citrons, pine-apples, lemons, pomegranates, bananas, grapes, peaches, apricots, pears, plums, tamarinds, mahogany, ebony, cedar, oak, dyewoods, and numerous other trees, plants, and shrubs, spring almost spontaneously from the soil, and render the labour of man almost unnecessary. As the traveller ascends from the sandy tract on the sea-shore, he beholds on every side magnificent forests filled with majestic trees, and adorned by the splendid colours of flowers and blossoms. In the midst of these are farms and plantations, which gleam with the freshest verdure of cane or corn; while over the levels roam innumerable herds of cattle. There are numerous ancient remains in this state.

The city of Vera Cruz, the capital of the state, is situated on the shores of the Gulf of Mexico, in Lat. 19. 11. 52. N., and Long. 96. 8. 45. W. It is well and handsomely built of madrepore; and its red and white cupolas, towers, and battlements have a splendid effect when viewed from the sea. Many of the houses are large, being built in the Moorish or old Spanish style, and generally inclosing a square court, with covered galleries. They have flat roofs, glass windows, and are well adapted to the climate. There is a tolerably good square, of which the Government House forms one side, and the principal church another. There are other churches, as well as monasteries and nunneries. Opposite the town, at the distance of about 800 yards, is a small island containing the strong castle of San Juan de Ulloa, which commands the town. The harbour lies between the town and the castle, and is very insecure. Vera Cruz is extremely unhealthy at all times; and during the warm season Europeans are exceedingly liable to become the victims of the *vomito prieto*, or black vomit. The city is surrounded by sand-hills and ponds of stagnant water; there is neither garden nor mill near it; and the only water fit for use is that which falls from the clouds. The trade of Vera Cruz is very considerable. Alvarado, a port about 36 miles to the S.E., and which constituted the seat of maritime commerce during the revolution, is built upon the left bank of a river of the same name, at the mouth of which there is a bar, rendering it inaccessible to vessels drawing more than 10 or 12 feet of water. Large ships must consequently be loaded or unloaded by means of lighters. The trade of Mexico, however, has either reverted to its old channel, or is shared by Tampico, a port which has risen into importance within these few years. It is situated about 120 miles N.N.W. of Vera Cruz, in Lat. 22. 15. 30. N., Long. 97. 52. W., being about 312 miles from Mexico. The population of Vera Cruz amounts to about 8000.

Another town in this state is Jalapa, from which a well-known drug takes its name. Formerly it was the great mart of New Spain for European goods, as the unhealthiness of Vera Cruz compelled traders to transfer their merchandise at once to this city, where a great annual fair was held. It has now, however, little commerce of its own, and is only a sort of resting-place between Vera Cruz and Mexico. Jalapa is indebted to the peculiarity of its position for the extreme mildness of its climate. The town stands upon a little platform 4500 feet above the level of the sea, and is protected from the N.W. winds by a ridge of mountains. The height is exactly that at which there is a continual humidity in the atmosphere; but this only imparts a balmy feeling to the air, whilst it gives a delightful freshness to the face of nature. The town is neatly built, although the streets are irregular; and the houses, without being remarkable for their size, are of a superior order. Jalapa is the seat of government for the state of Vera Cruz, and here a large garrison is kept. The population is about 16,000.

San Luis Potosi.

San Luis Potosi.—To the N.W. of Vera Cruz lies the state of San Luis Potosi, under which name, as a Spanish intendancy, were included Cohahuila and Texas, New Leon, Tamaulipas, and San Luis. The western portion of the state is quite mountainous, but towards Tamaulipas the Cordillera is somewhat broken, and a lower hilly country stretches out towards the S.E. The Panuco and the Santander are the only rivers, and the lagoons of Chariel and Chila the only two lakes of importance in the state. The climate of the mountain region and table-land is cold; while that of the lower elevations and flats towards the eastern boundary is much warmer, and at certain seasons very unhealthy. Maize, wheat, barley, and fodder are the principal agricultural productions of this state. Cattle are raised in large quantities. Wool and cotton fabrics, glass, leather, pottery, and hard wares are manufactured here to a considerable extent. The state of San Luis Potosi is divided into four departments, ten cantons, and fifty-two municipalities. In this state there are a number of rich mines, particularly those of Catorce, where a metalliferous ridge of mountains extends for many miles. Recently a profitable quicksilver mine was discovered in the jurisdiction of the hacienda of Villela, S. of the capital. With the exception of the capital, which bears the same name, it possesses no large town. San Luis, including the suburbs, contains about 35,000 inhabitants. It is well built, and contains a number of churches, monasteries, and public buildings. The exterior architecture of the sacred edifices is generally heavy, being overloaded with carved ornaments and ill-executed statues of saints; yet at a short distance they give a magnificent appearance to the town. The palacio, now the house of the provincial Congress, forms one side of the Plaza de los Armas, which has an excellent fountain of water in the centre. The *parroquia*, or cathedral, occupies a portion of the opposite side, and on its right are the soldiers' quarters. The two other sides are filled with shops and dwelling-houses. San Luis derives great advantage from its situation, as the natural depôt for the trade of Tampico with the northern and western states. Zacatecas, Durango, and other states receive through this channel a large proportion of their foreign imports; and since the building of the new town of Tamaulipas, which, from being on a more elevated spot than the old town (*pueblo viejo*) of Tampico, is less subject to the vomito, there is every appearance of a rapid increase in this branch of commercial intercourse.

Zacatecas.

Zacatecas.—To the W. and N.W. of San Lúis Potosi is situated Zacatecas, a state divided into eleven districts, viz., Zacatecas, Aguas Calientes, Sombrercté, Tlaltenango, Villanueva, Fresnillo, Jerez, Mazapil, Nieves, Piños, and Juchilipa. Zacatecas is a mountain country of the high plateau of Mexico, cut up by spurs of the Cordillera, and mostly arid and inhospitable. The region between San Luis Potosi and Sombrereté, and Mazapil and Zacatecas, is a broad plain, interspersed with a few swelling knolls and an occasional group of hills or small mountains. There are no rivers of any size in this state, and the country is unusually dry; water-tanks, draw-wells, and reservoirs are established on all the estates. The country, however, is particularly rich in its mineral productions, which constitute almost its sole wealth. Manufactures there are none, excepting in the capital, where there are a few cotton-spinners, as also at Aguas Calientes.

Zacatecas, the capital, is situated at the foot of an abrupt and picturesque porphyritic mountain, upon the rugged summit of which is perched a neat church and a small fortress. From the inequalities of the ground on which it stands the streets are short and crooked. Besides a very noble cathedral, it contains a number of churches and convents. Amongst the public buildings worthy of notice may be mentioned the mint, the finest in Mexico, and La Casa del Ayuntamiento, a magnificent edifice, where all the public offices are established, and where the Congress of the state assembles. This town contains about 25,000 inhabitants; and Veta Grande, a village in its immediate vicinity, numbers about 6000. Aguas Calientes is a small town situated on the banks of a stream of the same name, in a broad and fertile valley, 75 miles S. of Zacatecas. It is celebrated for its woollen manufactures; and in the neighbourhood are several thermal springs.

Yucatan.

Yucatan.—The state of Yucatan occupies the greater portion of the peninsula which separates the Gulf of Mexico from the Caribbean Sea. It is a vast alluvial plain, intersected by a mountain ridge which does not exceed 4000 feet in height. Upon some parts of this extensive territory maize, frijoles, rice, cotton, pepper, tobacco, and the sugar-cane are produced, besides dyewood, hides, and other articles. In the central parts the want of water is a very serious drawback to agriculture: the rainy season is very uncertain, and in many parts not even a stream is known to exist; so that in unfavourable years the inhabitants are compelled to have recourse for subsistence to the roots which the woods supply. This state contains numerous remains of ancient cities, which have been recently visited and described by Mr John L. Stephens and Mr Catherwood. The capital of Yucatan is Merida, situated on an arid plain 40 miles from the coast. It enjoys little trade, and contains only about 12,000 inhabitants. Campeachy is the principal commercial town; and here the logwood, which goes by the same name, attains its greatest perfection. The town contains about 9000 inhabitants.

Tabasco.

Tabasco.—Adjoining Yucatan is Tabasco, one of the smallest in the confederation, and previous to the revolution a province of the intendancy of Vera Cruz. A great portion of the state is extremely flat, and during the rainy season is laid under water, so that intercourse between the villages has to be carried on by canoes. The state is watered by numerous streams; but they are generally short and shallow, and have their mouths obstructed by bars. On the eastern boundary of Tabasco is the Laguna de Terminos, which is 45 miles long by 30 broad, and contains several large and beautiful islands. The climate of this state is exceedingly hot. Cacao, coffee, pepper, sugar, tamarinds, arrowroot, and some tobacco are cultivated; while indigo and vanilla grow wild in the forests. Game is very abundant, and the streams are well stocked with excellent fish. The capital, San Juan Bautista or Villa Hermosa de Tabasco, lies on the left bank of the Tabasco River, 70 miles from its mouth, and contains about 7000 inhabitants. Vessels of light draught can reach it from the sea; but its chief intercourse is carried on with the adjacent states and Guatemala.

Las Chiapas.

Las Chiapas.—Between Tabasco and Guatemala is situated the state of Las Chiapas, which formerly belonged to Guatemala, but which in 1833 joined the Mexican confederation. Comprehending the northern slopes of the table-lands of Guatemala, Las Chiapas is, throughout a considerable part of its territory, cut up into successions of ridges and valleys, which are rich in many of the finest tropical productions. It is divided into four departments and nine districts. The most important of the numerous rivers flowing from the mountains near the state of Tabasco to the Gulf of Mexico, are the Tabasco River, the San Pedro, the Usumasinta, and the Pacaitun. The climate of Las Chiapas is mild and temperate; and the chief productions are corn, cacao, sugar, tobacco, figs, apricots, and other fruits and vegetables; but a great part of the state is uncultivated and unexplored. The state is divided into four departments, and the capital is Ciudad Real, or San Cristoval de los Llanos, a handsome town, containing a cathedral, two chapels, four monasteries, a nunnery, and an hospital; with a population of 6000. The state of Las Chiapas, like that of Yucatan, contains many ancient remains.

Durango. DURANGO.—The state of Durango is bounded on the N. by Chihuahua, W. by Sinaloa, E. by Coahuila, and S. by Zacatecas and Jalisco. The main branch of the Great Cordillera runs through this state in a N.W. direction. The north-eastern portion of the state slopes gradually downwards towards the waters of the Rio Grande, while the south-western part consists chiefly of lofty table-lands and mountain spurs. The climate is healthy and cool; and its agricultural productions are similar to those of the other states in like circumstances. The chief rivers are the Rio Nasas, Rio Guanavas, and the Rio Florida; and the lagoons of Cayman and Parras are on its borders. Immense quantities of horses, mules, sheep, and cattle are reared in this state; indeed, its cattle and minerals constitute its chief wealth. Iron, silver, gold, lead, and other minerals are likewise abundant.

Durango, or, as it is often called, Victoria, the capital of the state, is situated 180 miles to the N.W. of Zacatecas, in the midst of a vast plain. Both the city of Victoria and most of the other towns of Durango, as Tamasula, Sianori, Mapimi, San Dimas, Canelas, Cuencamé, and others, take their origin from the mines. Before the discovery of those of Guarisamey, Victoria was a mere village, and in 1783 it contained only 8000 inhabitants. Its population now amounts to about 22,000. The principal streets, the Plaza Mayor, the theatre, and most of the public edifices, were built by Zambrano, a wealthy proprietor, who is supposed to have drawn from his mines at San Dimas and Guarisamey upwards of 30,000,000 of dollars. The towns of Villa del Nombre de Dios, San Juan del Rio, and Cinco Señores de Nazas are almost the only considerable places in the state unconnected with the mines. The great mineral wealth of this state holds out the most encouraging prospect of ample remuneration to those who engage in mining speculations; and there can be little doubt that ere long the advantages which Durango possesses will be duly appreciated by foreign or native associations of capitalists.

Chihuahua. CHIHUAHUA.—The state immediately adjoining Durango to the N. is that of Chihuahua. The great mountain chain of Mexico, which forms the connecting link between the Rocky Mountains of the north and the Andes of the south, is here known as the Sierra Madre, and occupies chiefly the western part of the state, where its elevation attains a great height, and at length descends abruptly till it is lost in the plains of Sonora and Sinaloa. The highest point of the Sierra Madre is said to be 8441 feet above the level of the sea. The greater portion of the state consequently lies on the plateau of Mexico, and only a small part of it on the western slope of the Sierra Madre. It is watered by a considerable number of rivers and streams; and the principal of its lakes or lagoons are those of San Martin, Guzman, Patos or Candelaria, Encinillas, and Castilla. Large numbers of the aborigines still occupy the lonelier portions of this state, and frequently annoy the peaceful settler. Chihuahua possesses a mild and temperate climate, a fertile soil, and vast mineral resources. Agricultural operations are not much carried on here, the chief source of its wealth being the mines and cattle. The gold, silver, and copper mines are exceedingly productive. Veins of iron, cinnabar, lead, sulphur, coal, and nitre have been found and explored, but owing to the disturbed and insecure condition of the state, are altogether abandoned. (For an account of CHIHUAHUA, the capital, see the article under that head.)

Sinaloa. SINALOA.—The state of Sinaloa is bounded on the S. by Jalisco, E. by Durango, S.W. by Chihuahua, N. by Sonora, and W. by the Pacific and the Gulf of California, along the shores of which it extends for about 200 leagues. The River Cañas divides it from Jalisco, and the River Mayo from Sonora. It is about 540 miles in length from S.E. to N.W., and has a breadth of about 150 miles. The surface is partly mountainous and partly level coast land. The coast region is little cultivated and thinly inhabited, being scorched by a burning sun; the central and eastern parts contain numerous table-lands and valleys; while the slopes of the mountains are thickly wooded with excellent timber. In the interior the air is mild and genial: in those parts where irrigation is practised abundant crops of grain are raised. Wheat, Indian corn, and barley, with cotton, sugar, and tobacco, are its chief agricultural productions. This state is also rich in minerals. The principal town is Mazatlan, a seaport-town and a place of considerable trade. It contains about 6000 inhabitants.

Sonora. SONORA is situated on the Gulf of California to the N. of Sinaloa. The western and southern portions of the state are generally flat. The eastern portion is mountainous, but contains many fine and productive valleys; this portion of the state is likewise rich in valuable mineral deposits. In the S., between the Rivers Mayo and Yaqui and the Presidio of Buena Vista, there is a fruitful region, which is also enhanced by a number of small lakes which form in different parts during the rainy season, and which are turned to good account by the agriculturists in the irrigation of their farms. The climate is warm throughout the year, but in spring is subject to rapid changes in temperature. A great portion of this state is still in the possession of the Indians, most of whom are still in a wild and savage state. The trade of Sonora is principally carried on at Guyamas, which is situated in a healthy region, and possesses one of the best harbours in Mexico. It contains about 3000 inhabitants. Petic, about 120 miles N.N.E from Guyamas, is a larger town, containing about 8000 inhabitants. It is the depôt for goods imported at the Guyamas, and designed for the northern district of Mexico.

Tamaulipas. TAMAULIPAS.—This state extends along the shores of the Gulf of Mexico, southward from the Rio Grandé del Norte, which separates it from the North American state of Texas. It has a coast-line of about 350 miles, and its breadth varies from 50 to about 160 miles. The coast is low and sandy, and fringed with lagoons varying from 4 to 18 miles in width, and divided from the gulf by banks of sand. The shallowness of the shores, and the dangerous bars which obstruct the mouths of the rivers, render navigation difficult and dangerous. In the northern part of the state, in the neighbourhood of the Rio Grandé, the country is comparatively level. South of this, however, and at some distance from the coast, the surface is varied by a succession of mountains, hills, and valleys, which gradually slope westwardly to the flats and sands of the sea-coast. The Cerro de Martinez, the Cerro de Jeres, the Cerro del Coronel, and the Sierras de la Palma and del Carico, are the

Political divisions.

most remarkable elevations. The territory is in general well watered; and fine valleys extend along the Rio Grandé, the Tigré, Borbon, Panuco, and Dolores. On the coast are the lagoons of La Madré, Morales, and Tampico. The climate of the interior is mild and healthy, but on the coast an intense heat prevails during the greater part of the year, which, combined with the rank vegetation and moisture, renders this region very unhealthy. The principal ports are Tampico de Tamaulipas and Metamoros, where a large coasting and foreign commerce is carried on to supply the middle and northern states of the republic. Matamoros is situated on the right bank of the Rio Grandé, about 30 miles from its mouth, and contains about 12,000 inhabitants. Tampico stands on the northern bank of the Panuco, about 5 miles from its mouth. The capital of the state is Victoria, formerly Santander, and contains about 12,000 inhabitants. Numerous remains of ancient edifices, &c., exist in this state.

New Leon.

New Leon.—To the westward of Tamaulipas lies the state of Nuevo Leon, which was colonized in the end of the sixteenth century by the Viceroy Monterey, who bestowed upon it the proud title of El Nuevo Reyno de Leon, or the New Kingdom of Leon. It lies among the first spurs or ridges of the Sierra Madré, and is interspersed with wide plains and fruitful valleys. The principal rivers, all of which flow easterly towards the Gulf of Mexico, are the Rio Tigré, San Juan, Rio Blanco or Borbon, and the Sabinas. The climate, except among the higher mountain ranges, is warm but salubrious. Agriculture has not been much practised in the state, the chief occupation of the landholders being the grazing of cattle. Lead and silver are said to be abundant; but mining operations are only carried on at two places, Cerralvo and Vallecillo. Salt is made at the salt mines on the banks of the Tigré. The capital of the state is Monterey, estimated to contain about 13,000 inhabitants.

Colima.

Colima.—This territory lies along the shores of the Pacific, and is bounded on the other sides by Jalisco and Mechoacan. Its surface is generally level, and here and there broken by ranges of hills. On the N.E. corner of the territory is the Mountain of Colima, the most western of the Mexican volcanoes, and which rises to the height of 9200 feet above the level of the sea. The climate is warm, and on the coast hot, but not unhealthy. Cotton, sugar, tobacco, and cacao are its chief agricultural productions; while on the coast large quantities of salt are made from sea-water. Rich iron deposits have recently been found here. The chief town is Colima, about 6 miles S. of the volcano, and containing about 20,000 inhabitants. Manzanillo, the port of Colima, is about 17 leagues W. of the capital, and a place of some trade.

Cohahuila

Cohahuila.—Adjoining to New Leon and Tamaulipas is Cohahuila, which is generally elevated, and being well sheltered from the N.W. winds, possesses a healthy climate. A considerable mountain chain stretches across the state in a north-westerly direction, and its surface is most luxuriantly irrigated by the numberless springs and streams which, bursting from these ridges, become tributaries to the Rio del Norté. Its pastures are clothed with rich natural grasses, and are admirably calculated for breeding, rearing, and fattening cattle; whilst its forests furnish abundance of wood, which is well calculated for every kind of construction. There are mines of saltpetre, copperas, alum, lead, tin, and copper, besides some silver in Santa Rosa, and gold in Sacramento. These mineral treasures, for want of population and of capital, have been rather ascertained than explored. The inhabitants are almost wholly of the white race, or with such slight mixture of the Indian blood as to make no distinction in colour worthy of notice. The native tribes within the province have been extinguished; but on the borders towards the N. and W. are several warlike tribes of Indians. In these parts also there are droves of wild cattle and horses, and herds of buffaloes. The capital of the state is Leona Vicario, or Saltillo, a large town containing about 20,000 inhabitants. It is situated upon the side of a hill branching off from the Sierra Madré, which in this quarter presents nothing but barren rocks; whilst the intervening valleys or plains are all nearly destitute of vegetation. The inhabitants are chiefly occupied in agriculture, and produce excellent wheat and barley, and great variety of fruits. The vines cultivated here make wine of very excellent flavour, and considerable strength.

Lower California.—The territory of Lower California comprehends that long narrow strip of land which extends from the northern boundary of the republic southward to Cape St Lucas, having on the E. the Gulf of Mexico and on the W. the Pacific. It is about 700 miles in length, and varies in breadth from 30 to 100 miles. The surface consists of an irregular chain of rocks, hills, and mountains, which run through its entire length, and which attain a height of nearly 5000 feet. Amid these ridges there are occasionally found a few sheltered spots of productive land; but it is for the most part a barren, dreary waste, and is one of the most unattractive countries in the warm or temperate regions. There are few streams or springs, few trees of any size; and the heavy rains, falling on the central ridges, carry down the sloping sides of the peninsula almost all the cultivable soil. Valuable mines of gold, silver, copper, and lead are known to exist in the peninsula, but only a few of these are worked, and that in a rude manner. The salt mines on the island of Carmen, in the Gulf of Mexico, are very productive. Among the islands of the gulf immense numbers of seals are constantly found, and the whaling grounds on the Pacific coast are of great value. During the sixteenth century the pearl fishery in the gulf produced a valuable revenue, but it has now dwindled into insignificance. The coasts of Lower California are flat, sandy, and irregular, frequently indented by coves, inlets, and bays; while many islands lie near and border them in the gulf. The climate is regarded as not unhealthy; the winter is short, and frost and ice are unknown. The heat of summer, however, is intense, parching the thin soil, and rendering life almost insupportable in the most exposed regions, or in the narrow and confined glens. The principal ports on the W. coast are San Quentin, which is said to afford a secure anchorage for the largest vessels, and Magdalena, which is much resorted to by whalers during the winter season. The only towns of importance in the peninsula are Loreto and La Paz; the latter the capital and seat of government. The population is almost entirely Indian or of a mixed race.

MEXICO, New, one of the territorial governments of the United States of America, is situated between Lat. 31. 20. and 38. N., and Long. 103. and 117. W., and has a length from E. to W. of 700 miles, and an average breadth of 400. It is immediately S. of the territories of Utah and Kansas, W. of Texas and the Indian territories, and has the Mexican States to the S., and California to the W., separating it from the Pacific Ocean. Its area, including a late addition, is 234,507 square miles, being five times the extent of the state of New York.

The Rocky Mountains cross the New Mexican territory from N. to S. The mountains of Guadalupe, Sacramento, Organ, Sierra Blanca, &c., are diverging ranges from the main chain of the Rocky Mountains. Among the Sierra Madre Mountains a height of 10,000 feet is reached above the high table-lands of the Rio Grande. This river, formerly called Rio Bravo del Norte, is the largest in the territory, draining the great valleys of the Sierra Madre and the Jumanes, &c. The Pecos River drains the eastern slope of these mountains; the Gila runs directly westward to the Colorado from its source on the Sierra Madre. The other rivers are,—the Puerco, the Canadian, Salinas, San Pedro, San Francisco, Colorado; none possessing much importance for navigation, except, perhaps, the Colorado. The Rio Grande, after it enters Texas, may be navigated many hundred miles by steamers. From the great elevation of New Mexico, it has a temperate climate. Some of the mountain-peaks are crowned with perpetual snow. Rains fall between July and October; but the country is too much parched, with the exception of a few favoured valleys, to hope for much agricultural development. More thorough explorations are, however, needed to pronounce absolutely in regard to it. In 1846 a military reconnoissance was made of it by Major Emory of the United States army, which is published among the official reports of the government. The notes are very full and interesting, and the following is a digest from them:—

"The country to-day is rolling, almost mountainous. Grass begins to show itself; the soil is good enough apparently, but vegetation is stunted. Our eyes for the first time are greeted with waving corn; all the intermediate country is broken and covered with a dense growth of pine, piñon, and cedar. The hills rise 1000 feet above the road. Found excellent grass on the Rio Pecos. Mountains rise from 1000 to 2000 feet above the road. Scenery wild; granitic sands and rocks in abundance on the road to Santa Fé. Cedar and pines are crowded together. Halted in a valley covered with some grama and the native potato in full bloom. On leaving the narrow valley of the Santa Fé, the country presents nothing but barren hills, utterly incapable, both from soil and climate, of producing anything useful." Referring to the Rio del Norte:—"The river impinges close to the hills below La Joya; two sand-hill spurs, overlaid with fragments of lava and trap, close the valley, just leaving space in the river to pass between. On either side is excellent grass, shaded by large cotton woods. The whole prairie is the loveliest I have seen in New Mexico. The valley of the Del Norte, as we advance, loses what little capacity for agriculture it possessed. The plants of New Mexico are,—Cacti of endless abundance and gigantic size, the disagreeable *Larrea mexicana*, *Obine canescens*, *Tessaria borealis*, *Diotis lanata*, *Franseria acanthocarpa*, varieties of mezquite, a species of *Malva Convolvulus*, an unknown shrub found in the bed of all deserted rivers, large grama nearly equal to oats, and *Dalea formosa*, a branched shrub, 3 feet high, with beautiful purple flowers. The table-lands to the west are covered with sand and large round pebbles. The soil of New Mexico is in general barren, but in many places adapted to the culture of the grape. On the whole, however, this territory may be regarded as an important military possession of the United States. Wherever the eye wanders huge mountains are seen, of black volcanic formation, of very compact argillaceous limestone, tinged at times with scarlet from the quantities of red felspar. Through these the Gila has cut its way with infinite labour, assisted by the influx of the Prieto, the Azul, and San Carlos rivers. The Prieto is said to flow down from the mountains freighted with gold, its sands being impregnated with the precious metal. The Gila now presents an inhospitable look; the mountains of trap, granite, and red sandstone cluster together in irregular and confused strata. The valley, not more than 300 feet from base to base of these perpendicular mountains, is deep and well grown with willow, cotton-wood, and mezquite. The Gila and San Pedro meet in a deep bottom overgrown with cotton-wood, mezquite, chamiza, willow, and black willow. There is little or no grass; and the formation along the river is a conglomerate of sandstone, lime, and pebbles, with deep caverns. The precipices are of granite and limestone, with seams of basalt and trap; vast boulders of pure quartz at times obstruct the way. The whole of North Mexico, embracing New Mexico, Sonora, &c., as far north as the Sacramento, is the same in physical character, and differs little in climate or products. Nowhere can fertilizing showers be relied upon to any extent for the cultivation of the soil. The earth is destitute of trees, and in great part of any vegetation. A few feeble streams flow in different directions from the great mountains that traverse this region. These streams are separated by mountains, or by plains without water or vegetation, and, so far as they are useful to man, may be called deserts. Culture is therefore confined to those narrow stripes of land which are capable of irrigation, and is conducted only on the sternest principles of coercion."

The whole of the New Mexican territory probably abounds in mineral wealth, which will doubtless be rapidly developed. Gold is found frequently on the Rio Grande and the Colorado, and mines have been worked in different localities. Copper, iron, and gypsum are found, and also coal and lead. A mining company in New Mexico (1857) reports as follows:—

"We are progressing well in our explorations and operations. The Aravaca rancho lately purchased for the company contains many silver mines of rich ores, besides some gold placers and copper and lead mines. We have lately discovered and occupied ten veins of silver ore near the Ceno Colorado, between Sopiri and La Aravaca, of promising richness. The principal vein, named in honour of our old friend and president 'The Heintzleman Mine,' yields upon assay thirty marcos to the carga of 300 lb., or nearly L.20 in silver to the 100 lb. ore. The ore is abundant, and we have a force of Mexican miners employed in its extraction, but have no bellows or means of smelting and refining."

When the census of 1850 was taken, it appeared that there were 3750 farming interests in New Mexico, containing 166,201 acres of improved, and 124,370 acres of unimproved land; the farms were valued at L.350,000, and the implements at L.16,200; the average value of these interests being but L.96, or $\frac{1}{12}$th the value of those in New Jersey, and $\frac{1}{15}$th the value of those in Louisiana. The following were the leading agricultural products:—Horses, asses, and mules, 13,733; neat cattle, 32,977; sheep, 377,271; bushels wheat, 196,516; Indian corn, 365,411 bushels; hay, 373 tons; 15,688 bushels peas and beans; 4236 gallons molasses; 8467 lb. tobacco; 32,901 lb. wool; 2363 gallons wine. Total value of property in the territory, L.1,000,000.

The capital invested in manufactures in 1850 was L.13,000; raw material used, L.23,000; product, L.52,000. The particulars are not published.

The commerce of New Mexico amounts to very little, and the annual imports for the United States were said to reach in 1846, L.100,000. This commerce constituted what was called the Santa Fé trade, and was conducted overland from Missouri in waggons. The most of the waggons, however, continued on their way to the Mexican provinces of Sonora and Chihuahua; and the whole extent of the commerce reached several millions of dollars. Much of it is now conducted by the way of Texas and the Rio Grande. Santa Fé, the chief town, had in 1850 a population of 4846, and San Miguel, 2008. Major Emory considered the inhabitants as the poorest in the territory, and says that the houses are built of mud or bricks, and in the Spanish style, generally of one storey, but very comfortable within. The thick walls make them warm in winter and cool in summer. The city is dependent upon the distant hills for wood. Every description of produce is dear.

In 1850 there were 73 churches in the territory, all Roman Catholic, possessing property to nearly the value of L.20,000, and having accommodation for 28,160 persons. The number receiving education was 466; and 25,089 persons over twenty years of age, or 61 per cent. of persons of that age in the territory, could neither read nor write. Two newspapers were published, circulating annually 38,800 copies. Pop. (1850) exclusive of Indians,—whites, 61,525; free coloured, 22; total, 61,547. The number of dwellings was 13,453. Of the total population, 58,415 were born in the territory, 772 in other parts of the United States, about 370 in Great Britain, and 215 in Germany; total foreign, 2063. The Indian population was 45,000 or 50,000.

The government of New Mexico consists of a governor appointed by the president of the United States, who is also superintendent of Indian affairs; a council of 13 members, elected every two years; and an assembly of 26 members, elected annually. The judiciary are appointed by the president.

Scattered throughout this extensive territory are many curious and extensive ruins, the relics of an advanced population of Indian or Aztec origin long since passed away. It constituted a Mexican province until conquered and purchased by the United States. In 1850 the territorial government was created; and in four years afterwards its dimensions were increased by the purchase of what is called the Wessilla Valley, embracing about 27,000 square miles. The territory has been making but small advances in population or wealth, and it will be long before it can take an important place in the affairs of the nation.

MEYER, FELIX, a landscape painter, was born in 1653 at Winterthur, canton of Zürich, Switzerland. After receiving lessons in his art from a painter at Nuremberg, he studied under Ermels, whose style he adopted. He then visited Italy for a short time, but finding that the climate did not agree with his health, he returned to Switzerland, and found free scope for the exercise of his genius in depicting the sublime scenery of his native country. He was remarkable for the ease and rapidity with which he executed his designs; and these qualities on one occasion were the means of extending his fame beyond the limits of his own country. Having arrived in the course of his travels at the Abbey of St Florian in Austria, he was requested by the abbot to give his advice about two large rooms which he wished to have painted in fresco; a work which the artist he had employed seemed unable to perform. Meyer immediately began to describe the designs he would recommend; and as he went on, with a piece of charcoal in his hand, rapidly sketching the various objects of the landscape, he excited the admiration of the abbot to such a degree that he engaged him to paint the whole. Although the landscapes of this artist are deservedly famous, he was not so successful in painting figures; and in some of his pictures those parts have been done by Melchior, Roos, and Philip Rugendas. Meyer died in 1713.

MEYER, *Johann Heinrich*, a German artist, was born in 1759 at Stäfa, on the Lake of Zürich, in Switzerland. He studied at Zürich under Füssly for some time; and in 1784 went to Italy. At Rome he met Goethe, with whom he formed a friendship so close, that the artist generally went by the name of "Goethe-Meyer." He also visited Naples, Venice, and other places, and returned to Switzerland in 1787. In 1792 he went to Goethe at Weimar, where he was made professor in the School of Design; and in 1795 he visited Italy again, and lived in Naples and Florence till 1797, when he returned through Switzerland to Weimar. Here he lived for many years in close and familiar intercourse with Goethe, whom he assisted in many of his works on art. Meyer was appointed in 1807 director of the academy of Weimar; and died at Jena in 1832. His paintings are few. The most important are an allegorical frieze in the palace of Weimar, and some drawings and water-colour sketches of ancient remains and the works of the old masters. He is chiefly famous as a writer on art, and his principal work is entitled *Geschichte der Bildenden Künste bei den Griechen*, Dresden, 2 vols., 1824. A third and a posthumous volume, in continuation of the history of art, especially in Rome, was edited by Reimer, and published at Dresden in 1836. He also edited the works of Winckelmann in 8 volumes.

MEYER, *Jacques*, a historian, was born in 1491 at Vleteren, near Bailleul in Flanders. After receiving his education at Paris he entered the church, and subsequently established a school at Ypres, by which he acquired considerable renown, and which he afterwards removed to Bruges when appointed to the church of St Donatien there. This school he finally gave up when he became curate of Blankenburg, where he died in 1552. His principal works are,—*Flandricarum Rerum Decas*, Bruges, 1531; and *Annales Rerum Flandricarum*, Antwerp, 1561.

MEYRICK, SIR SAMUEL RUSH, K.H., an eminent antiquary, descended from the ancient family of the Meyricks of Bodorgan in Anglesea, was born on the 26th August 1783. After taking his bachelor's degree at Queen's College, Oxford, at the age of twenty he made what his father considered an imprudent marriage, which led to his being disinherited. Meyrick practised law for many years in connexion with the Ecclesiastical and Admiralty courts. In 1810 he published his first work, the *History and Antiquities of the County of Cardigan*, when he was chosen a fellow of the Society of Antiquaries; and in 1814 he produced, in conjunction with Captain C. H. Smith, a work on the *Costume of the Original Inhabitants of the British Islands*. But the great work on which his fame as an antiquary particularly rests is his Arms and Armour, published in 3 vols. 4to, 1824, under the title of *A Critical Inquiry into Ancient Armour as it existed in Europe, but more particularly in England from the Norman Conquest to the reign of King Charles II.; with a Glossary of Military Terms of the Middle Ages.* After having rendered material assistance in 1826 in arranging the arms and armour of the Tower, and of the collection at Windsor, Meyrick had the honour of receiving from William IV. in 1832 the Hanoverian order, and was shortly afterwards made a knight-bachelor. In 1828 he built Goodrich Court on the Wye, arranged specially for the display of his collection of ancient armour, of which Joseph Skelton in 1830 gave an account in his *Engraved Illustrations of Ancient Armour*. Meyrick's last work of any importance was *Lewis Dwnne's Heraldic Visitation of Wales*, completed in 1846. Besides assisting in the compilation of Fosbroke's *Encyclopædia of Antiquities*, and writing the descriptive matter of Shaw's *Specimens of Ancient Furniture*, Sir Samuel R. Meyrick was a frequent contributor to the *Archæologia*, the *Gentleman's Magazine*, the *Analyst*, the *Cambridge Quarterly Magazine*, and the *Cambrian Archæological Journal*. He died on the 2d April 1848, in his sixty-fifth year.

MEYWAR. See OODEYPORE.

MÈZE, a seaport-town of France, in the department of Herault, is situated on the lagoon of Thau, 19 miles S.E. of Montpellier, and 5 N.W. of Cette. The harbour, which is protected by moles, is capable of receiving vessels of 60 tons. The inhabitants are employed to a considerable extent in the manufacture of brandy and salt; and the trade in these and in corn, wine, &c., is of some importance. In the neighbourhood of Mèze is the old abbey of Vallemagne, of which the church and cloisters, built in the thirteenth century, are still in perfect preservation, and are considered equal to any similar edifice in France. Pop. 4986.

MÉZERAI, FRANÇOIS EUDES DE, an eminent French historian, the son of Isaac Eudes, a surgeon, was born at Rye in Lower Normandy in 1610, and took the surname of *Mézerai* from a hamlet near Rye. After completing his studies at Caen he proceeded to Paris, where he procured the place of commissary at war, which he held during two campaigns. He then shut himself up in the college of St Barbe, in the midst of books and manuscripts; and in 1643 published the first volume of the *Histoire de France*, which he completed in 1651. This work surpassed all previous histories of France, and its author was rewarded by the king with a pension of four thousand livres. In 1668 he published an abridgment of his History of France in 3 vols. quarto, which was well received by the public; but he inserted in that work the origin of most of the taxes, with very free reflections, which led to the withdrawal of his pension. Annoyed at this treatment, he resolved to write on subjects which could not expose him to such disappointments; and accordingly he composed his treatise on the origin of the French, which added greatly to his fame. He was elected perpetual secretary to the French Academy; and died in the year 1683. He is said to have been so extremely negligent of his person, that one morning he was actually seized by the *archers des pauvres*, or parish officers, a mistake at which he was highly diverted. He used to study and write by candle-light at noonday in summer; and even lighted his visitors to the door. Having during his life affected a sort of religious scepticism, he recanted on his deathbed, and told his friends to "remember that Mézerai dying was more to be believed than Mézerai living." His merits as a writer are not of the highest order; but his works, whilst often coarse in style, are generally clear, direct, and forcible. In addition to the works already referred to, Mézerai published,—*Une Traduction de l'Histoire des Turcs de Chalcondyle*, Paris, 1662; *Une Traduction Francaise du Traité de Jean de Salisbury, intitule "La Vanité de la Cour,"* Paris, 1640; *Traité de la Verité de la Religion Chrétienne*, translated from the Latin of Grotius, Paris, 1644; *Histoire de la Mère et du Fils*, that is, of Mary of Medicis and Louis XIII., Amsterdam, 1730.

MEZIÈRES, a town of France, capital of the department of Ardennes, is situated on the Meuse, which here, making a bend in its course, nearly surrounds the town; 120 miles N.E. of Paris, and 80 N.W. of Metz. The town is ill built. Its chief importance is derived from the strength of its position and fortifications, which consist of walls, a citadel, and other defences, by Vauban. The principal building is a Gothic church of the fifteenth century, remarkable for its handsome portals and curious bas-reliefs. There are also several other churches, an hospital, town-hall, theatre, arsenal, and other buildings. The manufactures consist of leather and cutlery; and the trade, which is inconsiderable, is chiefly in linen and woollen stuffs, and leather. Mezières was besieged in 1521 by Charles V. with 20,000 men, and was about to be abandoned and destroyed by Francis I. when the Chevalier Bayard offered to take the command, and to hold the town against the emperor. His offer having been accepted, with only 2000 men he successfully resisted for six weeks the army of Charles. Bombs are said to have been first used in this siege. In 1815 Mezières held out for two months against the Prussians, but was at length obliged to capitulate. Pop. (1851) 3970.

MEZO-BERENY, a town of Hungary, in the county of Bekes, and 7 miles N.W. of the town of that name. The inhabitants are chiefly employed in the cultivation of the vine and olive, and in the rearing of cattle. Pop. 7900.

MEZO-HEGYES, a village of Hungary, in the county of Csanad, 33 miles E. of Szegedin. This village is only remarkable for the large stud of 3000 horses established here by Joseph II. in 1785. The horses are of great excellence, and the stables are large and handsome buildings. This establishment annually furnishes, in time of peace, 1000 horses to the Austrian army. Pop. 149.

MEZO-KOVESD, a market-town of Hungary, in the county of Borsod, 7 miles E. of Erlau. The town contains two churches, a school, and barracks for cavalry. Four fairs are held here annually. Pop. 6570.

MEZO-TUR, a market-town of Hungary, in the county of Heves, on the right bank of the Beretyo, 24 miles S.E. of Szolnok. It has three churches, considerable manufactures of pottery, an annual fair, and some trade. Pop. 15,673.

MEZZOFANTI, JOSEPH CASPAR, *Cardinal*, son of Francis Mezzofanti and Gesualda dall' Olmo, was born at Bologna, September 17, 1774. His father, who was a carpenter, and who designed him for the same handicraft, placed him, while a mere child, at a dame's school, from which he was soon removed to one of the free schools of the city under the care of the brethren of the Oratory. Father Respighi, a learned and benevolent priest of that congregation, perceiving the extraordinary talents of the boy, prevailed upon his father to place him at a school of a higher class conducted by the Abate Cicotti, and eventually at one of the celebrated "Scuole Pie," from which so many eminent Italian scholars have been produced. Several of the teachers in this school were foreign ex-Jesuits,—Spanish, Portuguese, Mexican, German, and Swedish; and it was from this early opportunity of intercourse with foreigners, and of familiarity with foreign languages, that Mezzofanti's love of linguistic studies received its first impulse. He early evinced a disposition to embrace the ecclesiastical state; and though his father at first opposed this resolution, he consented in the end, and the youth entered the pontifical seminary of Bologna, probably in the year 1786. An illness, however, with which he was seized about his fifteenth year, caused a considerable interruption of his studies, and his theological course was not completed till the year 1797. Of his scholastic and collegiate studies few details, beyond the names of his preceptors, are preserved; and the only notable indication of his future eminence that has been recorded is the prodigious quickness and tenacity of his memory. On one occasion he repeated verbatim a folio page of Chrysostom after a single reading; and (although little is known of the circumstances under which some of them are acquired) it is ascertained that, before he completed his collegiate studies, he had mastered not only the Latin, Greek, and Hebrew languages, but also Arabic and Coptic, together with Spanish, French, German, and Swedish.

In September 1795 Mezzofanti was promoted to priest's orders, having just completed his twenty-third year. A few weeks previously he had been appointed professor of Arabic in the university, and he commenced his lectures in the following December. This office, however. he held but a short time. On the annexation of Bologna to the Cisalpine Republic, an oath of adhesion to the new government was tendered to all officials, civil as well as military. Mezzofanti declined to take this oath; and although an offer was made to him to dispense with the oath, provided he would but present himself at one of the semi-public reunions in the Palazzo del Governo, he persisted in his refusal, and was in consequence deprived of his chair. For many years from this time his circumstances were exceedingly straitened, as his parents, now advanced in years, and his only sister and her numerous family, depended almost entirely upon him for support, and his only resource was the precarious income derived from private tuition, chiefly in languages. In the beginning of 1803, however, he was appointed assistant librarian of the Institute of Bologna; and in the November of the same year he was reinstated in his former professorship; or rather was reappointed, with the more comprehensive title, "professor of oriental languages and of Greek;" but, in the manifold political vicissitudes of the period, he was again doomed to a disappointment similar to that which had before befallen him. The professorship of oriental languages was suppressed by a decree of the viceroy of the kingdom of Italy in the year 1808; and Mezzofanti was once more thrown upon the precarious occupation of a private teacher for support until the year 1812, when he was appointed assistant librarian of the university. On the restoration of Pius VII. in 1814, he was again installed in his professorship; and in the following year was named chief librarian of the university,—an office which he continued to hold in conjunction with his professorship as long as he remained in Bologna.

Meanwhile, his progress in languages during these years had been rapid and untiring. His sacred duties as volunteer chaplain in the hospitals, which at this time were constantly crowded with wounded or invalid soldiers of the various armies which the revolutionary war brought together in Northern Italy, placed him in communication with natives of almost every country of Europe,—French, Spaniards, Germans, Poles, Hungarians, Bohemians, Croats, Russians, Swedes, &c. Religious zeal and charity, therefore, no less than the love of learning, became for him a motive of study; and in an incredibly short space of time he was able to master all the leading peculiarities of each new language that presented itself. In 1804 he sent to the celebrated orientalist John Bernard de Rossi of Parma a series of compositions in twelve languages; and as these were most probably learned languages, it may be fairly supposed that this number by no means represented the full extent of his acquirements at that date. He himself relates that his pastime was to turn every opportunity of study to account. The hotel-keepers used to give him notice of the arrival of all strangers at Bologna, and whenever the new arrival promised to bring a new language, or any special opportunity of improvement in an old one, within his reach, he "made no scruple about calling on them, interrogating them, making notes of their communications, asking instruction in the pronunciation of their respective languages." His study of books kept pace with his cultivation of living instructors. He made it a rule to learn every new grammar, and to apply himself to the vocabulary of every strange dictionary, which came in his way. And, as his memory was not only singularly quick, but tenacious almost to a miracle, and as his faculty of analyzing and appropriating the grammatical structure of languages was all but intuitive,—an instinct rather than an intellectual effort,—it will easily be understood that, even with the scanty opportunities of practice which an inland city like Bologna afforded, his power of acquiring foreign languages was quickened or developed in the very exercise.

Accordingly, when the peace of 1815 again opened Italy to travellers, visitors from the various countries of Europe were amazed, as they arrived in Bologna, to find a provincial abbate, who had never quitted his native province, speak indiscriminately not only English, French, German, Russian, Polish, and all the leading European languages, but Turkish, Arabic, Hebrew, Greek, Persian, and the other languages of the East. When Mr Stewart Rose visited him, in 1817, he "never once, during long and repeated conversations in English, misapplied the sign of a tense—that fearful stumbling-block to Scotch and Irish." A Smyrniote servant who accompanied Mr Rose "declared that he might have passed for a Greek or Turk in the dominions of the Grand Seignior." With Baron Zach, the celebrated astronomer and editor of the *Correspondance Astronomique*, in 1820, he spoke in German, "first in good Saxon (the *crusea* of the German), and afterwards in the Austrian and Swabian dialects, with a correctness of accent that amazed him to the last degree." In the same interview he spoke to the baron in Hungarian "with a compliment so well turned, and in such excellent Magyar, that he was taken completely by surprise." He spoke Polish and Russian with equal fluency to one of the baron's companions, Prince Volkonski; and at a subsequent meeting he added two much more uncommon languages, Wallachian and Zingari. Captain (now Admiral) Smyth, who was also of the party, still survives to confirm the literal truth of these statements. Lord Byron, Lady Morgan, the Countess of Blessington, and several other English tourists, who followed in the track of Mr Stewart Rose, speak of Mezzofanti in terms equally extraordinary. With M. Molbech, a Danish traveller (still librarian of the Royal Library of Copenhagen), he conversed during a long visit in Danish, which he "spoke with almost entire correctness." With Dr Tholuck, the celebrated orientalist of Halle, he spoke in Arabic and in Persian, "slowly, but with great propriety and exactness;" and he even wrote impromptu for him a Persian distich after the manner of Hafiz, which Dr Tholuck praises for the elegance of its sentiment and the propriety of its language and rhythmical structure.

A reputation so extraordinary procured for him the offer of many eligible appointments in several of the capitals of Europe. He was invited to Paris in 1805, to Naples about 1810, to Rome in 1814, to Vienna in 1815, to Florence on several occasions; but he declined all these flattering and advantageous offers, and remained in comparative poverty at Bologna till 1831, when having been sent to Rome as one of a deputation to the newly-elected Pope Gregory XVI., after the suppression of the Bolognese revolution, he at last yielded to the earnest solicitation of that pontiff, and transferred his residence to the papal capital. He was appointed a domestic prelate of the pope and canon of the church of St Mary Major on his arrival; and in 1833, when Angelo Mai was transferred from the Vatican Library to the post of secretary of the Propaganda, Mezzofanti was installed chief keeper of the Vatican. He was at this time in his sixtieth year, but his energy had not yet undergone the slightest diminution. Soon after he reached Rome he made a journey to Naples, expressly for the purpose of studying Chinese in the Chinese college of that city; and though his health broke down during this visit, he subsequently resumed the study at Rome with such success as not only to compose and speak in this most difficult language, but even to preach to the young Chinese ecclesiastics in the college of the Propaganda! Among the students of this vast missionary establishment, too, he found many new fields of language open to him; and it is ascertained beyond all doubt, that, advanced as was his age when he settled in Rome, he subsequently acquired many additional languages, of which he had known nothing whatever during his residence at Bologna. Of these, besides Chinese already alluded to, may be mentioned several North American Indian languages, Californian, Maltese, Angolese, Amariñña (an Abyssinian language), and above all, Basque, in both dialects of which (Labourdain and Souletin) he learned to converse when he was nearly seventy years old!

In the year 1838 he was advanced to the cardinalate, conjointly with his friend, the distinguished scholar Angelo Mai. He was appointed head of several ecclesiastical congregations; but never held any office connected with the government. His elevation, however, brought no change in his literary occupations. He continued to pursue his favourite study with the same assiduity; he was still, as before, accessible at all times to strangers who sought his acquaintance; and to the last he never failed to pay a daily visit to the students of the Propaganda, with whom he loved to speak in their respective languages, and to whom he freely acted as instructor in any language which they desired to cultivate.

One of the most remarkable characteristics of his wonderful gift was the power which he possessed of passing suddenly in conversation from one language to another, without the slightest hesitation or the smallest trace of intermixture or confusion. One of his friends compares the completeness of the transition to a man's "passing from one room into another;" so utterly did he leave the first language aside from the moment he began to speak in the second. Another, describing its rapidity, says it was "like a bird flitting from spray to spray." The cardinal himself declared that from the moment he began to speak in a language, he thought, reasoned, saw, in that medium only, as though he possessed no other beside.

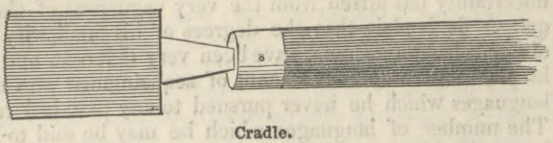
Visitors were amazed, too, to find him not alone perfectly master of the classical language of their respective countries, but often conversant with the various dialects of each to a degree really marvellous. To a German he would speak in the Swabian or Austrian dialects; to a Hungarian in any of the three dialects of Magyar; to a Spaniard in Castilian, Andalusian, or Catalan. He was familiar with several of the provincial dialects of English, and often amused English visitors by imitations of Yorkshire or Somersetshire provincialisms, or of the cockneyisms of a London cabman. Scotch, too, he was more conversant with than are ninety-nine out of every hundred Englishmen. He was even acquainted with these provincial subdivisions of several languages which are themselves but minor members of the European family; as, for example, the Dutch or Flemish. The secret lay in his prodigious memory. He often declared that he never forgot a word which he had once learned; and his memory was as ready as it was tenacious. His power of composing in these various languages was no less wonderful. He would write, quite impromptu, couplets or quatrains in any required language, according to the nation of his visitor; often, it is true, commonplace in sentiment, and exhibiting but little poetic talent; but displaying, nevertheless, singular command of words and extraordinary mastery of the rhythmical structure of the language, as well as of its principles of metrical versification. Many such little impromptus, in every language of Europe, are in existence. The same power he often exhibited on a larger scale, in the preparation or revision of the metrical pieces in various languages recited at the yearly academies of the Propaganda.

Nor was his knowledge confined to the languages of these various countries. All those who conversed with him attest that his familiarity with their several literatures was very great, and this not merely with the authors of the highest name in each, but with writers comparatively little read, and least of all likely to attract the notice of a foreigner. Of this fact, incredible as it may appear, there is the clearest evidence from travellers of all the principal nations—English, French, Germans, Spaniards, Russians, Poles, Hungarians, Bohemians, Danes, Swedes, Flemings, Dutch, and even Greeks, Armenians, Persians, Turks, and other orientals.

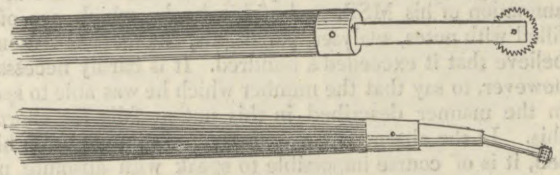
A good deal of uncertainty has existed as to the number of languages known by Mezzofanti, and considerable variety of statement has prevailed on the subject. Much of this uncertainty has arisen from the very vagueness of the inquiry. It is plain that the degrees of his familiarity with different languages must have been very different, and that he possessed a certain amount of acquaintance with many languages which he never pursued to any practical result. The number of languages which he may be said to have known in this way was indeed very great. From a report drawn up by one of his family, and founded on a careful examination of his MSS. and of his books, which are often filled with notes, analyses, paradigms, &c, there is reason to believe that it exceeded a hundred. It is hardly necessary, however, to say that the number which he was able to speak in the manner described in this notice falls far short of this. In the absence of any distinct statement from himself, it is of course impossible to speak with absolute precision; but from a detailed inquiry recently instituted both at Rome and in almost all the other European capitals, and even in the East, there is distinct evidence (marvellous as it may be deemed) of his having *spoken* (with various degrees of excellence, but yet sufficiently for the purposes of intercourse) between fifty and sixty languages, and of his having *known, less perfectly*, probably twenty others, in some of which he could converse less fluently, or at least initiate a conversation.

It will easily be supposed that Cardinal Mezzofanti's success as a general scholar must have, in great measure, been sacrificed to this one absorbing pursuit. But he nevertheless enjoyed a respectable reputation. In the sacred learning of his own profession he was well read. He was an earnest though not a very eloquent preacher. That he possessed considerable knowledge of mathematics is attested by an interesting conversation of his with M. Libri, the distinguished historian of mathematical science in Italy; and his visitors, from whatever country they came, generally found him familiar with the history of their respective nations. He was one of the most amiable of men, and his charity, even when his resources were most limited, was active and unceasing. He died at Rome during the absence of the papal court at Gaeta, March 15, 1849. His only published work is a panegyrical oration in memory of his first Greek master Father Emanuel da Ponte, printed at Bologna in 1820. (C. W. R.)

MEZZOTINTO, a word of Italian origin, signifying *half-painted*, is applied to a particular style of engraving from its near resemblance to painting. Its invention has been ascribed to Prince Rupert; but it is much more probable that the real originator of the art was Ludwig von Siegan, an officer in the service of the landgrave of Hesse. This art has reached its highest perfection among English engravers, whose portraits after Reynolds, Raeburn, Lawrence, &c., are worthy of the highest commendation for the elegance of their execution. The mezzotint process possesses the additional merit of enabling the artist to give transcripts of his pictures at a cost exceedingly moderate when compared with the great expense of line engraving. The process has been very much improved since the beginning of the present century, by the introduction of clever etching of the outline and shades along with the mezzotinto, which at once gives character, charm, texture, and consistency to the subjects represented. While the mode of laying the ground is so well known, that plates of every description can be procured by every preparer of copper or steel, it may nevertheless be requisite to give a brief description of the process, especially as the laying of the ground forms part of the work of artists. The instruments employed for this purpose are called *cradles*, from their rocking motion, and may be made by any blacksmith. They consist of pieces of properly tempered steel, prepared with teeth, and fitted into handles, as shown in the accompanying cut, and are of all dimensions adapted to be used by the hand. The teeth, which are of all degrees of fineness, are applied to the surface of the plate fixed upon the table, to which a rocking motion is applied in all directions, until a perfectly black ground is given to the plate by raising a barb or burr upon it which holds the printing-ink for the impression. Other instruments, such as scrapers and burnishers, are employed, and may be readily procured. Rulettos are also sometimes used for darkening or deepening any particular object or space, and can easily be obtained. The difficulty of the process, which can only be overcome by practice, consists in the laying of the ground, some portions of the work requiring coarser and others finer grounding. No special rules can be given for the rest of the process, which consists partly in scraping and partly in burnishing off, first the middle tints, and then the lights.



Cradle.



Rulettos.

It has been customary to give Le Blon of Frankfort's method of printing in colours in treating of mezzotinto, which is performed by various plates; but such modes of procuring coloured engravings may be better seen and understood by consulting Baxter's oil-colour painting from wood blocks, or Hullmandel's lithographic printing in colours, known by the name of "Cromo-Lithography," methods which have in great measure superseded the former.

MGLIN, a town of Russia, government of Czernigov, and 130 miles N.E. of the town of that name. It contains four churches; and has some trade in the agricultural produce of the neighbouring country, which is not very fertile. Pop. 6327.

MIAKO, Miaco, or Meaco, a city of Japan, and the ecclesiastical capital of the empire, is situated near the S. coast of the island of Niphon, about 240 miles W.S.W. of Yeddo; Lat. 35. 24. N., Long. 153. 30. E. The town stands in a wide plain, bounded in all directions by hills covered with trees and gardens, and is 4 miles in length by 3 in breadth. The houses are built for the most part of wood, and are two storeys in height; the streets are regular but narrow. The principal buildings of Miako are palaces and temples, both of which are very numerous, there being, it is said, 130 of the former, and not less than 6000 of the latter. Of the temples, the most remarkable are the *Fokosi*, an edifice of white marble, with numerous pillars of cedar wood in the interior, and a large statue of Buddha; and the temple of Kwanwon, which has an image of that deity even larger than that of Buddha. The Mikado, or ecclesiastical emperor of Japan, resides, with his attendants the *Dairi*, in a part of the town divided from the rest by walls and ditches. The court of this emperor, which is composed of all the most learned men in Japan, is in fact the principal college in the empire; and the greater part of the books published in Japan come from the Dairi and other learned men in Miako. The town is also remarkable as the chief seat of the manufacturing industry of Japan; the principal articles being carved ornaments and japanned wares. Pop. believed to be between 500,000 and 1,000,000.

MIAVA, a town of Hungary, in the county of Neutra, is situated on a river of the same name, falling into the March, 48 miles N.N.E. of Presburg. The inhabitants are of the Sclavonian race, and in religion they are for the most part Lutherans. There are two churches and a synagogue; manufactories of woollen stuffs, distilleries, saw-mills, &c. Miava has also some trade in hemp and flax. Pop. 9800.

MICAH, one of the twelve minor prophets of Scripture, was born in Moresheth of Gath, and, according to the inscription of the book, prophesied during the reigns of Jotham, Ahaz, and Hezekiah (B.C. 757–696), and was consequently contemporary with Isaiah. The genuineness and authenticity of the prophecy of Micah is unquestionable; although it is a matter of dispute whether the passage in chap. iv. 1–3 is borrowed from Isaiah ii. 2, 4, or that in Isaiah borrowed from Micah, or whether both be not derived from a common and more ancient source. Hengstenberg (*Christology*) strongly maintains Micah's originality; while De Wette (*Einleitung*) observes that we have the best reason for regarding the last years of Ahaz as the period of Micah's prophetic glory. The period of Micah's predictions, however, is fully attested by Jeremiah (chap. xxvi. 18, 19), where Micah is said to have foretold the destruction of Jerusalem in the reign of Hezekiah.

The most remarkable predictions contained in this prophet have been pointed out by Jahn, and are as follows:—1. The destruction of the kingdoms of Israel and Judah (iii. 12; vii. 13). 2. The Babylonian captivity, delivered 150 years before the event (iv. 10, 11; vii. 7, 8, 13). 3. The return from the captivity, and the tranquillity of the Jews under the Persian and Grecian monarchies, referring to events from 200 to 500 years distant (iv. 18; vii. 11; xiv. 12). 4. The heroic exploits of the Maccabees (iv. 13). 5. The establishment of the royal residence in Zion (iv. 8). 6. The birth and reign of the Messiah (v. 2). The style of Micah is remarkable for sublimity and vehemence, besides abounding in rapid transitions, elegant tropes, and piquant plays upon words. There are also several specimens of animated dialogue in this prophecy, especially in the second part, where the Lord is represented as conversing with his people, reproving their morals, threatening chastisement, and offering consolation by the promise of a return from their exile.

Micah is the third of the minor prophets, according to the arrangement of the Septuagint; the sixth according to the Hebrew; and the fifth according to the date of his prophecies. (See De Wette's *Einleitung*; Pocock's *Commentary on Micah*; Groseschopr's *Micah Uebersetzt*; and the *Introductions* of Jahn and of Eichhorn.)

MICHAEL I., Rhangabe, Emperor of Constantinople, was the son of Theophylactus, and grandson of Rhangabe, from whom he derived his surname. The Emperor Nicephorus honoured him with the hand of his daughter Procopia, and the office of master of the palace; but after the battle with the Bulgarians, in which that monarch was slain, and his son Stauracius was mortally wounded, the latter, while sensible that he could not long retain the purple, was opposed to Michael as his successor. Michael, however, was in 811 named emperor even before the death of Stauracius, and made an ineffectual attempt against his life; but he was unable to retain the throne against the opposition of the army, although the people were well disposed towards him. He retired to a convent after a reign of two years, and died in the year 845

Michael II., *Babbus*, or the Stammerer, Emperor of Constantinople, was born at Amorium in Phrygia, and was one of the principal officers of Bardanes. He assisted Leo V., his companion in arms, to obtain the throne, but afterwards conspired against him; and being convicted of treason, was condemned to be thrown into a fiery furnace. Before the sentence was executed, however, Leo was murdered by the other conspirators, and Michael was removed from his dungeon to the throne, even before his irons could be struck off. Michael was opposed by Thomas, another of the officers of Bardanes, who led 80,000 Asiatics against Constantinople, but was defeated and taken captive by the emperor, and treated with great cruelty. Michael died in 829, after a reign of nine years.

Michael III., Emperor of Constantinople, grandson of the preceding, succeeded his father Theophilus in 842 at the age of three, and was for some time under the guardianship of his mother Theodora. This emperor rivalled Nero in vice and cruelty; and neglected the loss of provinces for the sake of a victory in the chariot race. These excesses, along with the profane insults which he offered to the religion of his people, made him an object of universal hatred and contempt; and he was at last murdered by Basil the Macedonian in 867, after a reign of twenty-five years.

Michael IV., *The Paphlagonian*, Emperor of Constantinople, was raised to the throne in 1034 by Zoe, daughter of Constantine IX., the last of the Macedonian dynasty. This princess was married to Romanus III.; but becoming enamoured of Michael, her chamberlain, she poisoned her husband, and married her attendant. He, however, being of a weak character, and subject to epileptic fits, possessed the supreme power only in name, and was a mere instrument in the hands of his brother John. During his reign the Bulgarians made an incursion into Thrace and Macedonia, and Constantinople itself was in no small danger; but the indolent and infirm emperor, much to the surprise of friends and foes, put himself at the head of the army, and gained a victory, which compelled the invaders to retire. Michael returned in triumph to Constantinople, and shortly after died in 1041, after a reign of seven years.

Michael V., *Calaphates*, Emperor of Constantinople, and nephew and successor of the preceding, was the son of a caulker of ships, from whom he derived his surname, and was invested with the purple in 1041 by the influence of his uncle John. No sooner was he established on the throne than he banished his uncle and the empress Zoe, an act which raised a tumult against Michael, and put an end in 1042 to his short reign of four months. The dethroned emperor lived for some time afterwards in a monastery.

Michael VI., *Stratioticus*, Emperor of Constantinople, succeeded the Empress Theodora in 1056, being, as his surname indicates, of the military profession. His government was feeble in the extreme; and he was at last compelled to abdicate by Isaac Comnenus, who had defeated his army in Phrygia. Thus, after an inglorious reign of one year, Michael retired to a convent where he spent the rest of his life.

Michael VII., *Parapinaces*, Emperor of Constantinople, was the son of Constantine XI., and was appointed by his father in 1067 joint emperor along with his brothers Andronicus and Constantine. Michael, however, was in reality sole emperor, as his brothers were contented with mere empty titles and honours; but he was by no means fitted for the duties of his station, being a man of narrow mind, and a dabbler in philosophy and rhetoric. At length two generals of the name of Nicephorus, surnamed Bryennius and Botaniates, simultaneously rebelled against him, when Michael in 1078 resigned the purple, and retired into a monastery. He was afterwards made Archbishop of Ephesus.

Michael VIII., *Palæologus*, Emperor of Constantinople, was born, as his name indicates, of the ancient and noble race of the Palæologi, in the year 1234; and at an early age was so distinguished as a soldier and statesman as to be raised to the dignity of constable or commander of the French mercenaries. Although by his generosity and affability he gained the affections of the army and populace, his ambition rendered him an object of fear and suspicion to the court, and involved him in dangers from which it required all his courage and prudence to effect his escape. On the death of Theodore II., who had more than once unjustly attempted his life, Michael took part in the conspiracy by which Muzalon, one of the guardians of the young successor to the throne, was murdered; and succeeded in getting himself appointed regent in his stead. Shortly afterwards Michael was crowned emperor at Nice; and his reign was rendered illustrious by the recovery of Constantinople in 1261. This emperor died in 1282, after a troubled reign of twenty-two years, during the course of which, though stained with many cruelties and crimes, he restored by his vigour and ability the decayed fortunes of the Greek empire. (For further information respecting these emperors, see Constantinopolitan History).

MICHAEL'S MOUNT, St, a granite rock in Mount's Bay, county of Cornwall, England, about three-quarters of a mile S. of Marazion; N. Lat. 50. 7., W. Long. 5. 28. It is of a pyramidal form, 250 feet in height, and about a mile in circuit, and is joined to the land by a causeway, which is covered by the sea at high water. This has been supposed by some to be the place called by the Greeks *Ictis*, from whence they obtained tin; but this opinion is by no means certain. As early as the fifth century a chapel was founded here, which was an object of pilgrimage; and remains of a Benedictine priory, founded by Edward the Confessor, are yet to be seen. It was fortified, and a place of some importance in former times; and was taken by John de Vere, a follower of the House of Lancaster, in 1471; by the Cornish rebels in 1548; and by Colonel Hammond, in the civil war in 1646. The Mount is still fortified, having 3 batteries and 18 guns. There is a small village on the lower part of the peninsula, with a population of 163.

Michael, *St.* See Azores.

MICHAELIS, Johann David, a celebrated biblical critic of Germany, was the eldest son of the distinguished Hebrew scholar Dr Christian Benedict Michäelis, professor in the university of Halle, and was born at that place on the 27th of February 1717. His father devoted him at an early age to an academical life; and with that view he received his elementary education in a celebrated Prussian seminary called the Orphan-house, at Glanche, in the neighbourhood of his native place. He commenced his academical career at Halle in 1733, and took his master's degree in the faculty of philosophy in 1739. In 1741 he visited England, where his superior knowledge of the oriental languages, which was considerably increased by his indefatigable researches in the Bodleian Library at Oxford, introduced him to the acquaintance, and gained him the esteem, of the first literary men of the day, with several of whom, particularly Bishop Lowth, he afterwards kept up a regular correspondence. On his return to Halle, after an absence of fifteen months, he began to read lectures on the historical books of the Old Testament, which he continued after his removal to Göttingen in 1745. On the death of the chancellor Ludwig, whose lectures on German history laid the foundation of that peculiar knowledge of social law so admirably displayed in the *Mosaisches Recht*, Michäelis was appointed to catalogue the immense library of his former master. The result of his labours was published in 1745, and is considered an excellent specimen of such works. In 1746 he was appointed professor extraordinary, and soon afterwards professor of philosophy, in the university of Göttingen, where he afterwards, in the capacity of professor of theology and oriental languages, rendered the highest services to this institution. The next year he obtained the place of secretary to the Royal Society there, of which he was director in 1761, and he was subsequently made aulic councillor by the court of Hanover. In 1764 his distinguished talents, and a publication relative to his plan for an expedition to Arabia, procured him the honour of being chosen a corresponding, and afterwards a foreign, member of the Academy of Inscriptions at Paris, of which class the institution admitted only eight; and in the same year he became a member of the society of Häerlem. In 1775 Count Hopkin, who eighteen years before had prohibited the use of his writings at Upsal, when he was chancellor of that university, prevailed upon the King of Sweden to confer upon him the order of the Polar Star as a national compensation. In 1786 he was raised to the distinguished rank of privy councillor of justice by the court of Hanover; and in 1788 he received his last literary honour by being unanimously elected a fellow of the Royal Society of London. His great critical knowledge of the Hebrew language, which he displayed in a new translation of the Bible and in other works, raised him to a degree of eminence almost unknown before in Germany; and his indefatigable labours were only equalled by his desire of communicating the knowledge he had acquired to the numerous students of all countries who frequented his admirable lectures, which he continued to deliver in half-yearly courses on various parts of the sacred writings, and on the Hebrew, Arabic, and Syriac languages, to the last year of his life. He was forty-five years professor in the university of Göttingen, and during that long period he filled the chair with dignity, credit, and usefulness. He died on the 22d of October 1791, in the seventy-fourth year of his age.

The principal works of J. D. Michäelis are, in oriental literature, grammars of the Hebrew, Chaldee, Syriac, and Arabic languages, *Oriental u. exeget. Bibliothek*, 1781–85, 23 vols.; *Supplementa et emendationes ad Lexica-Hebraica*, Gött. 1784. In history, geography, and chronology, *Spicilegium Geographiæ Hæbrorum exteræ post Bochartum;* several discourses on Jewish law and antiquities, mainly embodied in his masterpiece the *Mosaisches Recht*, 1770-5, 6 vols., and translated into English in 1814 by Dr Alex. Smith, and entitled *Commentaries on the Laws of Moses.* His *Introduction to the New Testament* is familiar to the English reader through the well-known translation of Bishop Marsh.

MICHAELMAS, the feast of the archangel St Michael on the 29th of September, was instituted, according to Brady (*Clavis Calendaria*, vol. ii.), in A.D. 487. On Michaelmas-day, which is a stated rent-day in this country, there is an old custom, still kept up in certain districts, of having a roast goose to dinner, probably on account of the fact alluded to by an amusing writer in *The World*, No. 10, that "stubble geese are in the highest perfection" at that period. There are also a few quaint lines bearing on this point in Poor Robin's Almanack for 1695, beginning, "Geese now in their prime season are;" and there is a common saying that "if you eat goose on Michaelmas-day, you will never want money all the year round."

There was another custom on this day of which few traces, if any, now remain, viz., the baking and eating of *St Michael's cake* or *bannock.* Martin, in his *Description of the Western Islands of Scotland*, says that the inhabitants of Skye, and especially those of Kilbar village, have on this day a "general cavalcade, and several families bake the cake called St Michael's bannock, . . . and all strangers, together with those of each family, must eat the bread that night." Macauley, in his *History of St Kilda*, alludes to the same observance in that island, and adds, that all who ate the cake "had, of course, some title to the friendship and protection of Michael." (See Brand's *Popular Antiquities*, Bohn, vol. i., pp. 353, 367, 372.)

MICHAUX, ANDRÉ, a botanist, was born in 1746 at Sartory, near Versailles, and studied under Lemonnier the astronomer and Jussieu the botanist. In 1779 he travelled in England, from which country he introduced into France several new varieties of trees and shrubs; and in 1780 he explored the hills of Auvergne and the Pyrenees, and brought from Spain several sorts of grain, which were sent to the Jardin des Plantes at Paris. In 1782 he was sent by the Count of Provence, afterwards Louis XVIII., to Persia; but arriving there during a period of civil war, he was plundered by the Arabs of all but his books. Having obtained from the British consul at Bassora the means to continue his journey, he proceeded to Ispahan, where he cured the Persian monarch of a dangerous disease; and after spending two years in different parts of Persia, he was recalled, and returned to France with a fine herbarium and many valuable kinds of seed. In 1785 he was sent by the government to North America, where he travelled through a great part of the country, from Hudson's Bay to Florida, and from the Atlantic to the Mississippi. The French revolution, however, deprived him of the funds he had formerly received from the government; and his own means were soon exhausted, so that he was obliged to return to France. On his homeward voyage he was shipwrecked, and only escaped with his life and four boxes of specimens. He arrived in Paris in 1796; and notwithstanding the justice of his claims, the Directory gave him but a small indemnification for his losses, and that not till after three years of anxious expectation. But Michaux was able to bear the privations of poverty and neglect with the same patience and perseverance with which he had endured the hardships of his former adventurous life. He lived on the same coarse fare, and slept on the same bear-skin, in the midst of the luxury of Paris, as in the deserts and ruins of the East, or in the prairies and forests of the West. In 1800 he went to Madagascar, where he died in 1802. Michaux was the author of several books, of which the principal are,—*Histoire des Chênes de l'Amérique Septentrionale*, Paris, 1801; and *Flora Borealis Americana*, Paris, 1803.

MICHEL ANGELO BUONARROTI, perhaps the greatest master of the arts of design who has ever appeared, was born in the castle of Caprese in Tuscany, on the 6th of March 1474. His father, Ludovico di Leonardo Buonarroti Simone, was a descendant of the noble and illustrious family of the Counts of Canossa, and allied to the imperial blood. This circumstance had nearly occasioned the world the loss of the great artist; for when the strong bias of his mind became apparent, which occurred at a very early age, his father and uncles discouraged his pursuits, and treated him with harshness, conceiving that their family would be degraded should a scion of their race adopt the profession of artist. But objection, prejudice, and even persecution, proved useless when opposed to devoted attachment and irresistible genius. Michel Angelo received the rudiments of his education at Florence, the nursing-mother of the arts, and here he enjoyed ample facilities of gratifying his taste for drawing. Ludovico finding it hopeless to attempt to frustrate the intentions of nature, yielded at last to the advice of friends and the wishes of his son, who was accordingly placed under Domenico Ghirlandajo, a distinguished professor of the arts of painting and design. The youth was articled to serve three years; but, contrary to custom, instead of paying, he received a premium; an indubitable proof of his great merits, even at the age of fourteen. The original document by which he was engaged bears date April 1488. His earliest effort in oil showed that he was born to grapple with difficulties from which other men shrink, whilst his success proved that he was also destined to overcome them. The subject was "St Anthony beaten by Devils." In this little picture, besides the figure of the saint, there were crowded wild and grotesque forms and monsters, to which he was so intent upon giving an aspect of reality, that he painted no part without referring to some natural object. But painting did not engross the whole of his time and attention. The great patron of the arts at this period was Lorenzo de' Medici, who, for the purpose of elevating sculpture to a level with painting, opened a garden in Florence, which he amply supplied with antique statues, bas-reliefs, busts, and the like. Thither the youth of the city repaired to study the classic creations of antiquity; and it is scarcely necessary to say that it became the favourite haunt of Michel Angelo.

From copying the drawings and paintings of others, his attention was turned to the modelling of figures in clay, in imitation of the monuments of ancient art; and the transition from this, the initiatory step in sculpture, to the moulding of the marble into symmetrical forms, was natural, and speedily withdrew his mind from every other study. The vigilant and practised eye of Lorenzo soon discovered the genius of the youthful sculptor in the execution of a mask representing a laughing faun. His father was sent for, and requested to resign Michel to the care of the family; and this being complied with, apartments were allotted to him in the ducal palace. Here he received every indulgence and attention, being treated with parental affection, and allowed to pursue the bent of his genius, not only without interruption, but cheered and encouraged by the cordial approbation of his munificent patron. Amongst the works which he executed under these favourable auspices was a bas-relief representing the "Battle of the Centaurs;" on viewing which at a future period of his life, he lamented that he had not confined himself to a branch of art wherein he had so soon attained such excellence. This is the strongest evidence which could be produced of the rare merits of the sculpture; for artists almost uniformly speak disparagingly of their early efforts.

On the death of Lorenzo, which happened about two years after he had entered his service, Michel Angelo with a heavy heart returned to the paternal mansion. Nothing belonging to Lorenzo was inherited by his son Pietro except the territorial possessions of the family; and although the young artist continued to pursue his studies with unabated zeal, little patronage or encouragement was to be expected or obtained from a frivolous debauchee. The pusillanimity of this person soon distracted the councils of Florence; and Michel, to escape the storm which he saw impending over that city, retired to Bologna, but returned in about a year afterwards, when tranquillity had been restored. About this period there prevailed a sort of mania for the antique. Whilst the discoveries of antiquity created a new era in art and literature, the importance of which can never be too highly estimated, many ignorant individuals, smitten with the enthusiasm of the time, betrayed their want of judgment by the indiscriminate manner in which they lavished their praise on these remains; and Michel Angelo resolved to take advantage of the popular excitement. He executed a "Sleeping Cupid;" and having stained the marble in such a way as to give it the appearance of a genuine antique, it was transmitted to a proper person in Rome, who, after burying it in his vineyard, dug it up, and then reported the discovery. The pardonable trick completely succeeded for a time, and the statue was bought by a cardinal for a considerable sum; but of this Michel Angelo received only a small portion. Such deceptions, however, seldom remain long concealed; the officious zeal of friends, or the vanity of authorship, usually brings about the exposure of a successful imposition. After the mask was laid aside, and the real artist became known, he received a flattering invitation to visit Rome. Thither he accordingly repaired: and whilst there he executed a statue of "Bacchus," another of a "Cupid," and a group of the "Virgin weeping over the dead body of Christ" for St Peter's church, together with a cartoon representing St Francis receiving the *stigmata*.

The celebrated gonfaloniere Pietro Soderini, well known as a patron of genius, having been elected to guard the peace and protect the liberties of Florence, Michel Angelo returned to that city. With the sanction of the new chief magistrate, he was allowed to appropriate to his use a huge block of marble, which, after having been much injured by Simone des Fiesole in attempting to shape it into a colossal statue, had for many years lain neglected in the court of the Palazzo Vecchio in Florence. Out of this he executed a gigantic statue of David, which gave great satisfaction. He also cast a figure in bronze of the size of nature, and a group of "David and Goliath;" but, that his hand might not "lose its cunning" in the sister art, he painted a "Holy Family." This picture is preserved in the Florence gallery; and it is the only painting in oil by Michel Angelo now remaining the authenticity of which is not disputed. Having been commissioned to ornament the hall of the ducal palace with a cartoon, he chose for the subject an event connected with the war between the Florentines and Pisans. The work represents the Florentine soldiers, who, alarmed by an unexpected assault whilst bathing in the Arno, are getting out of the water with the utmost expedition, and preparing for action; and although only outlined in charcoal, chalk, and the like, it was considered as the most extraordinary production which had appeared since the revival of the arts in Italy. In the meantime, Julius II. having been raised to the pontifical throne, Michel Angelo was invited to the Vatican, whither he repaired without finishing the cartoon; but being disgusted with Rome, he returned to Florence, and completed the design. The painting of the picture itself, however, was never begun. Political events, and a second invitation from Julius II., again attracted him to the Eternal City, and he was employed by his holiness to construct a magnificent mausoleum, which, although immediately commenced, was interrupted during its progress, first on account of a misunderstanding between the artist and the pope, and afterwards from other causes. The artist repaired to Bologna, and political events having brought the pope to this city, a reconciliation took place. In a few days Julius II. ordered a colossal statue of himself to be executed in bronze, which Michel Angelo finished in sixteen months, and returned to Rome at the end of June 1508. This statue was the personification of severe majesty, with one hand raised in the attitude of benediction; but being somewhat at a loss how to dispose of the left, he asked the pope whether he would like a book to be placed in it, when the warlike pontiff promptly replied,—"A sword rather; I was never given to letters." He was, however, disappointed in his hopes of being allowed to proceed with his great architectural undertaking; for the pope had changed his mind, it is alleged through the jealousy of Bramante, and the artist was requested to decorate with pictures the ceiling and walls of the Sistine chapel. But his previous disappointment was forgotten in his subsequent triumph. This stupendous work of genius excited the highest admiration, which contemporary opinion and the judgment of after ages have confirmed; yet only eighteen or twenty months were spent in its execution.

After the death of Julius II. in 1513, the papal throne was filled by Leo X., whose magnificent reign forms an era in the intellectual history of modern times. Yet, strange as the fact may appear, the life of Michel Angelo during his pontificate is nearly an entire blank. He was employed in extracting marble from a quarry which was

Michel Angelo.

wrought with difficulty, and in constructing a road over intricate swamps and through mountainous ridges, for the purpose of conveying it to the sea. Leo X. died in 1521, and under his successor Adrian VI. Michel Angelo employed himself upon the monument of Julius. The reign of Adrian was short; and on his death Clement VII. was raised to the papal throne. The confusion with which the civil affairs of Rome were soon overwhelmed drove the artist to Florence, where he continued his architectural and other works for the chapel and library of S. Lorenzo, and executed a statue of Christ. His talents as an engineer were likewise put in requisition for the defence of the city. Before commencing the works he visited Ferrara, then the best fortified town in Italy, and was received with the utmost courtesy by the Duke Alphonso, who showed him every part of the works, and at the same time requested a specimen of the artist's abilities either in sculpture or in painting. A picture of "Jupiter and Leda" was the result; but this great production is generally supposed to have been lost. Michel Angelo was enabled to complete the fortifications of Florence before the siege of the city commenced; and, as in the case of Syracuse, the genius of one individual for a considerable time proved more than a match for thousands of armed men and the mightiest engines of war. By treachery the city passed into the hands of the enemy; but the great artist, although he had shown the dexterity of Archimedes in frustrating the designs of the besiegers, did not share the fate of the great geometrician. The finishing of two monuments for the Medici family was the price of his liberty.

Tranquillity being restored to Italy, Buonarroti returned to Rome; and although frequently interrupted, both by Clement VII. and by his successor Paul III., he at last completed the monument to Julius II. It consists of seven statues, amongst which is the celebrated one of Moses, a production evincing, in a higher degree than any of his other sculptures, that character of majesty and sublimity which more or less pervades them all. His next work was the painting of the "Last Judgment" in the Sistine chapel, which was finished in 1541; and so great was the admiration excited by this mighty effort of genius, that many persons came from distant parts of Italy to see it. He subsequently painted the "Martyrdom of St Peter" and the "Conversion of St Paul," which cost him great fatigue, as age was beginning to impair his physical energies. But that his intellectual powers still retained their pristine vigour, the church of St Peter's, the most splendid monument of his genius and success as an architect, affords ample evidence. This fabric was begun by Julius II. in 1506, and being successively intrusted to Bramante and Antonio de San Gallo, by this transference from hand to hand it was in danger of becoming a huge incongruity. On the death of Antonio de San Gallo in 1546 Michel Angelo was appointed architect; and notwithstanding the jarring and complexity of the original designs, he succeeded in simplifying and harmonizing the whole. The work proceeded for a time with considerable rapidity. But he was occasionally withdrawn from it to other things, such as the building of bridges, the superintendence of which might have been safely intrusted to some inferior person. During the latter years of his life the papal chair was filled by several pontiffs, some of whom forwarded, and others retarded, his great undertaking, employing him in the construction of chapels and other buildings. Nor did he live to witness the completion of this splendid edifice, the greatest and most magnificent Christian temple on earth. He was carried off by a slow fever on the 17th of February 1563. His obsequies were celebrated as became the memory of so unrivalled a genius.

Michel Angelo was of the middle stature, bony in his make, and rather spare, but broad over the shoulders. His complexion was good; his forehead was square, and somewhat projecting; his eyes were of a hazel colour, but rather small; and the general effect of his countenance was impaired by a blow which he had received in youth.

The character of Michel Angelo as an artist has already been delineated in this work by a masterly hand. (See the article Arts, *Fine.*) Grandeur of conception is the quality which distinguishes his works from those of all other artists who have appeared in modern times. Whether he excelled most in painting, in sculpture, or in architecture, it would not be easy to determine. He has left the noblest specimens of human genius in each department of art. He is the Milton of artists. Things beyond the visible diurnal sphere were within the range of his imagination; and when he stoops to earth, he invests nature with an ideal grandeur and majesty. His boys are men, his men are a race of giants: his demons are the evil spirits of Dante and Milton made visible; and his angels are the offspring of the sky. The Sistine chapel is allowed to be the most finished work of art in the world; and its perfection is owing chiefly to Michel Angelo's divine paintings. The whole wall behind the altar is covered by his picture of the "Last Judgment;" the vaulted ceiling represents the creation of the world, and around it are prophets and sibyls. In the sublime painting of the "Last Judgment," terrible power is the predominating feature. The good and the bad, angels and devils, crowd the scene, and Christ is represented in the act of judging, or rather of condemning. His complete knowledge of anatomy, which he constantly studied, enabled him to represent in the most perfect manner the human figure in every possible attitude, and to express pain and despair through all their gradations. His other pictures exhibit the same daring sublimity of conception and power of execution. The church of St Peter's at Rome is the most splendid triumph of his architectural talents. His style in architecture is distinguished by grandeur and boldness; and in his ornaments the untamed character of his imagination is frequently apparent, in his preference of the uncommon to the simple and elegant. In sculpture his statue of Moses is universally acknowledged to be the noblest monument of his genius, displaying, more than any other of his numerous works in this department of art, all the great qualities of his mind.

Michel Angelo was likewise an author, and excelled both in verse and prose. His poetry, like his art, was powerfully influenced by the Platonic philosophy to which he seems to have formed an early attachment through his connection with the Platonic Academy of Florence. His poetical pieces consist of sixty-two small poems, named madrigals, and sixty-four sonnets, besides a few pieces of greater length, of which the most touching is an elegy on the death of a brother. Some of these poems are the light, airy creations of gay fancy; but the greater part—particularly his sonnets, which comprehend his most beautiful effusions—are of a much graver cast, and are characterized by lofty thought and noble sentiment, expressed in strong, energetic, and elegant language. His sonnets are generally of a highly abstract nature, and are not unfrequently rendered painfully obscure by the subtle allegorical style which Dante had so popularized in Italy. (See an elegant essay by E. Taylor, on *Michel Angelo considered as a Philosophic Poet*, and accompanied by various translations, London, 1846.)

Lives of Michel Angelo were published during the artist's lifetime by Condivi and Vasari. The most recent, and in many respects the most valuable, biography of Michel Angelo is that entitled *The Life of Michel Angelo Buonarroti, with Translations of many of his Poems and Letters; also Memoirs of Savonarola, Raphael, and Vittoria Colonna*, by John S. Harford, Esq., D.C.L., 2 vols., London, 1857.

Michelozzi.

MICHELOZZI, Michelozzo, a Florentine sculptor and architect, was born about the year 1396. He was in his youth a pupil of Donatello, and soon displayed great genius and skill in executing marble and bronze statues. He was much attached to the service of Cosmo de' Medici, for whom he built a palace in Florence, now known by the name of the Palazzo Riccardi. This building is remarkable as being the earliest in Florence built after the modern rules; and as combining convenience as a dwelling with simplicity and beauty of architecture. When Cosmo was banished in 1433 Michelozzi followed him to Venice, where he erected the library of the convent of San Giorgio Maggiore, and designed several other edifices. In 1434 he returned with his patron to Florence, where he continued to exercise his art with such success, that he was appointed a member of the Florentine magistracy. After the death of Cosmo, Michelozzi continued to enjoy the favour of his son Pietro, for whom also he planned many buildings. He died at the age of sixty-eight, about the year 1470; but neither the date of his birth nor that of his death is exactly known.

MICHIGAN, one of the United States of North America, is bounded on the N. by Lake Superior; E. by Lake Huron, the Strait and Lake of St Clair, the Strait of Detroit, and Lake Erie, all of which separate it from Canada; S. by the states of Ohio and Indiana; and W. by Lake Michigan and the state of Wisconsin. It lies between 41.40. and 47.30. N. Lat., and between 82. 12. and 90. 30. W. Long., and has a total land area of 56,243 square miles. This state consists of two large peninsulas, separated from each other by the Straits of Mackinaw, and known respectively as the Northern and Southern; the former, formed by Lakes Superior and Michigan, is about 320 miles in length and 130 in extreme breadth; while the latter, formed by Lakes Michigan and Huron, has a length of 283 miles and an extreme breadth of 210 miles. These two peninsulas are very different from each other both in aspect and nature. The Northern is mountainous in its western part, some of the heights having an elevation of 2000 feet. The Wisconsin or Porcupine Mountains, which form the watershed between Lakes Michigan and Superior, attain an elevation of about 2000 feet in the N.W. portion of this peninsula. Towards the centre of this division there is a high table-land, broken by numerous hills, and extending E. as far as the Pictured Rocks, on the coast of Lake Superior. These rocks consist of masses of sandstone, formed by the continued action of the wind and waves into fantastic shapes, resembling ruined temples, castles, &c. The E. part of the peninsula from this point to its extremity consists of an undulating tract of country, sloping gradually down to the coasts on either side, which consist on the N. of sandstone rocks, and on the S. of limestone. The rivers of this part of the state are not of great size or importance; and those that flow to the N. have generally a rapid descent, and abound in picturesque falls and rapids. The principal of those which flow N. are,—the Montreal, the Ontonagon, the Huron, the St John's, and the Chocolate; and of those flowing S., the Menomonee and the Manistee. The Montreal and the Menomonee partly form the boundary between this state and that of Wisconsin. The southern peninsula consists of a varied surface of hill and dale, not rising in any part to a great elevation, but everywhere considerably above the level of the lakes, and having in many places steep coasts, from 100 to 300 feet in height. A ridge of hills traverses the country from S. to N., somewhat to the E. of the centre, and separates the waters of the rivers flowing E. to Lake Huron from those flowing W. to Lake Michigan.

In the southern part of this peninsula there are extensive plains or openings, as they are generally called by the inhabitants, covered more or less thickly with scattered oaks of different kinds, with here and there clusters of hickory. The numerous knolls which rise in all directions, the rivers, which are fringed with belts of wood, and the extensive and luxuriant meadows which occur in many places, combine to render this country one of the richest and most beautiful in scenery of any in the United States. Further to the N. there are dense forests, interrupted now and then by small prairies occupied by farms. Across the middle of the peninsula, from Saginaw Bay westward, a stripe of land extends, which is entirely covered with pine forests. This region is about 25 miles in breadth; and the unbroken forests of pines give to the country a dark and gloomy appearance. To the N. of this region beech and maple trees again become predominant, and the pines are only scattered here and there among them. The principal rivers of this peninsula are,—the St Joseph's, the Kalamazoa, the Grand, the Maskegon, and the Manistee, which flow into Lake Michigan; the Au Sable, and the Saginaw, flowing into Lake Huron; and the Raisin, flowing into Lake Erie. The geological character of the rocks of the northern peninsula of Michigan is principally primitive; those parts, however, near Lake Michigan exhibit a more recent formation; and the southern peninsula is chiefly secondary, being similar in its nature to the western part of the state of New York; while there are numerous boulders of primitive rock scattered over every part of this state. The northern peninsula is very rich in minerals, and possesses copper mines, which are in all probability among the richest and most extensive deposits of that mineral in the world. It is chiefly found in the Kewenaw peninsula, a piece of land jutting out into Lake Superior, from which the state of Michigan sent to Washington a block of copper several tons in weight, and nearly pure. This block is now to be seen built into the wall of the National Monument, bearing the arms of Michigan and this inscription,—"From Michigan: an emblem of her trust in the Union." Iron is also found in great abundance to the S.W. of the copper region; and the state has also lead, gypsum, peat, limestone, marl, and coal; but these have not yet been worked to any great extent. The soil of the southern peninsula is rich and fertile; and although the northern peninsula is in general barren, yet even here there are some tracts of great fertility. The climate of the northern part is severe, and the cold in winter intense; while in the S. it is much milder and more temperate than those parts of the eastern states which lie in the same degree of latitude. Cultivation, however, has not extended beyond the southern part of the lower peninsula, since the tide of emigration has rather passed through Michigan on its way to the countries farther W. than made any permanent settlements there. The quantity of cultivated land in the state amounted in 1850 to 1,929,110 acres; and the produce in the same year consisted of 5,641,420 bushels of Indian corn, 4,925,889 of wheat, 2,886,056 of oats, 2,359,897 of potatoes, and 472,917 of buckwheat; besides 2,043,283 lbs. of wool, 7,065,878 of butter, 1,011,492 of cheese, 2,439,794 of maple sugar, 404,934 tons of hay; live stock worth L.1,668,486; market produce, L.3,070; fruit, L.27,635; and butcher meat, L.276,735. The manufactures of the state of Michigan have not as yet made much progress, owing to the recent period at which this country has been settled; but in 1850 there were in Michigan 1979 establishments of various sorts. Among these there were 15 woollen factories, employing 129 hands and L.19,583 capital, and producing annually 141,570 yards, valued at L.18,800; 64 forges, furnaces, &c., employing 362 hands, and producing 5430 tons, to the value of L.62,645; several breweries and distilleries, employing 98 hands and L.29,047 capital, and producing 901,220 gallons; 6 tanneries, with L.59,583 capital, and producing leather to the worth of L.75,828; besides many other establishments.

The state of Michigan has been considerably improved by railways, two of which were begun by the state, but afterwards sold to private companies. The Michigan Central Railway extends from Detroit westward through the centre of the state to New Buffalo, and has a total length of 284 miles; the Michigan Southern, which, in connection with the Indiana Northern, extends from Monroe to Chicago, a distance of 243 miles. There are, besides, several smaller lines and branches. The position of Michigan, nearly surrounded by the largest fresh-water lakes in the world, is extremely favourable for its commercial prosperity; and this is further increased by the number and excellence of its harbours all along the coast, which surpass in both of these respects those of any other lake state. The number of vessels built in the state in the year ending June 30, 1855, was 27; and their tonnage, 7844. The value of the exports from Michigan in the same year was L.118,436; and that of the imports was L.58,620. The government of the state is elected by general suffrage every second year; and consists of a governor, with a salary of L.208 a-year, and a lieutenant-governor, who presides in the Senate, and receives 12s. 6d. a-day during the sitting of the legislative body. This body consists of a Senate and House of Representatives; the former containing 32, and the latter 66 members; and both popularly elected for two years. Michigan sends four members to the National House of Representatives; and has six votes in the election of a president of the United States. The judiciary consists of a supreme court, circuit courts, probate courts, and justices' courts. The franchise extends to every white man or civilized Indian, not a member of a tribe, above the age of twenty-one, and who has resided for a certain time in the state. The present constitution received the sanction of the people in 1850. The question of a general revision of the constitution is to be submitted to the people every sixteen years; but any change may be made on receiving the approval of two-thirds of each branch of the legislature, and being afterwards ratified by a majority of the electors.

The public debt of the state, November 30, 1855, was L.497,908; and on the 1st November 1856 it was L.489,056. The receipts for the year ending November 30, 1855, amounted to L.122,583, which, together with a balance of L.115,178, makes up a total of L.237,761; and the expenditure for the same year was L.130,162; leaving a balance of L.107,599. The state contained in December 1855, 4 banks, with an aggregate capital of L.152,174, and a circulation of L.119,638. According to the census of 1850 there were in the state 362 places of worship, of which 103 belong to the Methodists, 67 to the Presbyterians, 58 to the Baptists, 42 to the Roman Catholics, 29 to the Congregationalists, 25 to the Episcopalians, 12 to the Lutherans, 7 to the Quakers, 6 each to the Dutch Reformed Church and the Universalists, and 7 to minor sects. The total amount of church accommodation was 118,892 sittings, and the value of the whole church property, L.150,667. The government of Michigan pays considerable attention to the subject of education; and there is a fund set apart for the support of the schools in the state, which amounted in 1852 to L.119,935, and in 1854 to L.288,393. Besides this fund, which is obtained by the sale of public lands, there was raised by taxation in 1854 for the schools of the state L.73,266. The number of schools supported by these means was, in 1850, 2714, with 3231 teachers and 110,455 scholars. Besides these, Michigan had 37 schools, with 71 teachers and 1619 scholars, not supported by the state.

The university fund belonging to the state amounted in 1854 to L.94,255; and L.14,508 was raised by taxation in that year for the support of the school and township libraries, which then contained in all 121,201 volumes. The state contains 3 colleges, with 22 professors and 308 students; and a normal school opened in 1853. The principal of the other institutions are,—the asylum for the deaf, dumb, and blind, opened in 1854; the asylum for the insane, opened in the same year; the house of correction for juvenile offenders, opened in 1856; and the state prison at Jackson, which contained, November 30, 1854, 246 convicts. Capital punishment has been abolished in this state since 1848; and criminals convicted of murder are now imprisoned for life, with hard labour, in the state prison. Michigan is divided into 64 organized and 21 unorganized counties: and the capital of the state is Lansing.

The country now occupied by the state of Michigan received its first European settlement from the hands of the French soon after the middle of the seventeenth century. At the peace of 1763 it came, with the other French possessions in North America, into the hands of the British. On the expulsion of the French, the celebrated Indian chief Pontiac seized the opportunity to rid the country of the whites, and accordingly instigated a simultaneous rising among the Indians, who surprised and took all the forts in the country, massacring the inhabitants, with the exception of Detroit, which held out until relieved by British troops, who subdued the Indians, and freed the colonists from farther danger. The American revolution followed soon after; and the country now forming the state of Michigan came into the possession of the Union in 1796, and was made a territorial government in 1805, with Detroit for its capital. In 1812 it became the theatre of the war between Britain and the United States. Detroit was surrendered to the British in that year by General Hull, and the whole country was overrun by the British and Indians; but not long after they were finally expelled by General Harrison. Previous to 1830 the inhabitants of this country were chiefly Canadian French, but at that time it began to be occupied by emigrants from the other states, especially those of New England. Thus, while formerly little had been done to improve the culture or products of the land,—the French being contented idly and ignorantly to follow the customs of their fathers,—now that a more enterprising and energetic race of settlers had succeeded them, the country made rapid advancement in wealth and prosperity. In 1837 Michigan was admitted as one of the United States, having then a population of nearly 100,000. According to the census of 1850, the state contained,—whites, 395,071; free persons of colour, 2583: total, 397,654.

Michigan, *Lake*, one of the five great lakes of North America, is situated between 41. 30. and 46. N. Lat., and between 85. 50. and 88. W. Long.; having a length of 330, and a breadth of 90 miles, with an area of 20,000 square miles. The lake is fed by a number of rivers from the adjoining country, the principal of which are,—the Grand, Maskegon, St Joseph, and Kalamazoo, from Michigan; the Calumet from Indiana; the Chicago from Illinois; and the Milwaukee and Sheboygan from Wisconsin; and it discharges its waters through the Straits of Mackinaw into Lake Huron. Michigan has not many large bays, the largest being Green Bay, on the W. shore, chiefly in Wisconsin, more than 100 miles in length, and varying in breadth from 15 to 35 miles. On the E. coast the principal indentations are Little Traverse Bay and Grand Haven. Lake Michigan has few islands, and these are situated chiefly near the N.E. extremity. The shores are generally low; and the water seems to be gradually retiring from the eastern shore, and making encroachments on the western. The depth of the lake is between 900 and 1000 feet; and the surface is about 600 feet above the level of the sea. Though inferior in size to Lake Superior, this lake is in some respects second to none of the great American lakes. It extends farther to the S. than Lake Superior, and its shores thus enjoy a climate more mild and a soil more fertile than is found farther north. Its position is also highly favourable for commerce, being connected at once with the Mississippi and with the eastern coast of America; with the former by the Fox River, Lake Winnebago, and the Wisconsin River, as well as by a railway from Chicago to Galena; and with the latter by the railways through the state of Michigan and along the coast of the lakes. The commerce of the lake is accordingly very great, and continually increasing. The principal harbours on its shores are,—Green Bay, whose imports in 1851 amounted in value to L.400,000, and exports to L.200,000: Two Rivers, imports in the same year, L.23,958; exports, L.23,500: Grand River, imports, L.45,822; exports, L.55,223: St Joseph's, imports, L.111,720; exports, L.173,316: Manitowoc, imports, L.22,234; exports, L.16,067: Port Washington, imports, L.188,417; exports, L.29,052: Sheboygan, imports, L.271,855; exports, L.25,355: Milwaukie, imports estimated at L.3,035,702; exports at L.542,880: Racine, imports, L.306,884; exports, L.215,530: Kenosha, imports, L.272,262; exports, L.137,756: Waukegan, imports, L.129,132; exports, L.40,587: Chicago, imports, L.5,085,500; exports, L.1,168,056.

MICIPSA, King of Numidia, was the son of Masinissa, and succeeded his father in 148 B.C., along with his two brothers Gulussa and Mastanabal,—the kingdom being divided by Scipio between the three, in such a way that Micipsa possessed Cirta, the capital, in his portion of the inheritance. Soon afterwards, by the death of his brothers, Micipsa became sole monarch, in which position he continued till his death in 118 B.C., when he left his crown to his two sons Adherbal and Hiempsal, along with his nephew Jugurtha.

MICKIEWICZ, Adam, the most illustrious poet of Poland, was born at Nowogrodek in Lithuania in 1798, of a noble but poor family. From the district school of his native village he passed to the gymnasium of Minsk, and in 1815 to the university of Wilna, where his uncle was one of the professors, and where our own poet Campbell was once a candidate for the office of regent. This university, since suppressed by the Russian government, was then celebrated as a school of mathematics and natural science; and Mickiewicz early showed a strong inclination for chemistry and natural history, but gave no indication at that time to his friends of being possessed of any talent for verse. His first collection of poems appeared in two slim volumes at Wilna in 1822, after he had received the appointment of professor of classical literature at Kowno. They were received with extraordinary enthusiasm by the public; and the general voice of his country, and of all Sclavonic nations, assigned him the name of the "Polish Byron," and pronounced him the greatest poet of Poland. The larger portion of these poems, however, which consist mainly of ballads, remind the reader rather of Monk Lewis than of Byron. They are founded on the wild heathen superstitions and old pagan ballads of the Lithuanian peasantry, which the poet in his boyhood had gathered up out the obscure and neglected remnants of a dialect presenting the closest affinities with the Sanscrit. Besides the ballads these early volumes contain two longer poems of superior value. One of them, *Grazyna, a Lithuanian Tale*,—said to have inspired the unfortunate heroine Emilia Plater, who fought so bravely in the Polish ranks against Russia in 1830,—is the story of a Lithuanian princess who fell fighting in her husband's armour at the head of his retainers, rather than permit him, through private jealousy, to join his forces to the enemies of his country. The other, *Dziady* (*The Ancestors*), is a wild and irregular drama, full of powerful but revolting poetry, inspired by loathsome superstition and dark horror. He was assailed by Dmochowski, the Polish translator of Homer, among other critics, for his "romantic" innovations; but, despite this critical hostility, a company of young poets rapidly sprung up in and around Wilna, and formed themselves into the "School of Mickiewicz." But he was not destined long to enjoy in peace the honours of the poetical chief. His friend Zan had formed a society at Wilna for the cultivation of the Polish language and literature, of which the enthusiastic poet and a number of the alumni of the university were members. The jealousy of Russia was excited, and the society was dissolved. The indefatigable Zan, after repeated attempts to reorganize his cherished association, was condemned in 1824 to perpetual imprisonment; while his friend Mickiewicz and others escaped with a sentence of perpetual banishment in the Russian interior. The Polish poet was conveyed to St Petersburg whither his fame had already travelled, and he was received in the literary circles of that capital with great marks of respect. Here in 1824, while Byron was dying at Missolonghi, the Polish Byron, Adam Mickiewicz, and the Russian Byron, Alexander Pushkin, first met; and a keen sympathy soon sprung up between the illustrious Polish exile and the leading men of letters of the Russian capital. But genial literary intercourse and a spirit of revolution seemed to the watchful mind of despotism to be all but synonymous terms; and Mickiewicz got prompt orders to leave St Petersburg for Odessa. A tour in the Crimea resulted in a collection of *Crimean Sonnets*, which met with great success,—the author little dreaming that he should live to witness far other materials for moralizing on the "Steppe of Eupatoria," and the "old castle of Balaclava," than he found in the records left by the cultivated Greek, the enterprising Genoese, and the relentless Turk, on that memorable peninsula. Mickiewicz was invited to form one of the household of Prince Galitzin, governor of Moscow; and was subsequently permitted to return to the capital, where he published his *Conrad Wallenrod* in 1828, a romantic tale of great power, founded on a real historical character of Lithuania. The book, though breathing a deep spirit of freedom, escaped the political censorship of St Petersburg, though not of Warsaw and Wilna, by a dexterous preface, which informed the reader that the subject was chosen because it belonged entirely to the past, and because it could have no relation to the interests of the present. Having obtained permission to travel, Mickiewicz visited Goethe at Weimar, and had just made the acquaintance of Fenimore Cooper at Rome when news of the insurrection of Warsaw of 1830 reached him. He was too late to join his countrymen in their unsuccessful struggle, and he resolved to retire to Dresden, where he composed another part of his dramatic poem of *Dziady*. He makes himself the hero, and introduces more than one of his fellow-exiles by their real names. The first scene, which is placed in the corridor of the Basilian convent on the night of Christmas, is written with such immense power that it was said by an able critic to place the author on a level with Goethe. It was published at Paris in 1832, where his last long poem, and some say his finest, of *Pan Tadeusz* (*Sir Thaddeus*), appeared two years afterwards.

The star of Mickiewicz had now reached its zenith. On the establishment of a chair for the Sclavonic languages and literature in the College of France in 1840, the choice of Mickiewicz as professor was considered a peculiarly happy one. Unfortunately it turned out the very opposite. He had fallen under the influence of a religious charlatan, named Tomianski, some years before, who persuaded him that he had cured Madame Mickiewicz of a serious illness by means of mesmerism. The daring imagination of the poet, by long brooding over the dark mysteries accompanying such phenomena, plunged him into a sea of the wildest fanaticism. After a few brilliant lectures on Sclavonic literature, he addressed his audience on "the worship of Napoleon," and the "Messiahship" of some mysterious Pole, who, in 1844, proved to be the quack mesmerist. The deluded poet had to leave Paris; but he was permitted to retain the nominal professorship till 1851, when he was made sub-librarian at the Arsenal. He was sent on a mission to the East by the French emperor in 1855; and died at Constantinople on the 27th of November of the same year. His remains were removed to France, and interred at Montmorency, near Paris. No poet of Europe, during the last quarter of a century, had achieved so much as Mickiewicz, and his name stands unquestionably first in the literature of his country. His prose works, however (one of which, *The Polish Pilgrimage*, has been translated into English), do not occupy a high position. An edition of his works was published in 4 vols., Paris, 1856, entitled *Pisma Adama Mickiewicza, na nowo przejrzane, dopelnione*, &c.

MICKLE, William Julius, the translator of the *Lusiad*, was the son of Mr Alexander Mickle, a Scottish clergyman, who had formerly been an assistant to Dr Watts in London, and one of the translators of Bayle's Dictionary. He was born at Langholm in Dumfriesshire in 1734; and after his father's death he came to Edinburgh to reside with his uncle, who was a brewer there, and who admitted him to a share of his business. Not being qualified to succeed in this calling, however, he went to London about the conclusion of the war of 1755, to procure a commission in the marine service. In this he was disappointed; but he introduced himself to the first Lord Lyttelton, who encouraged him to persevere in his poetical studies.

From the time of Mickle's arrival in London till the year 1765 it is not known how he employed his time. In that year, however, he engaged himself as corrector to the Clarendon press. From this time till 1770 he published several small pieces in prose and verse, which brought him into some notice, the principal of which were *Pollio*, an elegiac ode (1765), and *The Coneubine*, written in imitation of Spenser (1767), and afterwards published, with alterations, under the title of *Sir Martyn*. He also wrote against Arianism and Deism in his Letter to Dr Harwood, and in his *Voltaire in the Shades*. His tragedy of the *Siege of Marseilles* proved a failure, and was never produced. When not more than seventeen years of age, he had read the *Lusiad* of Camoens in French, and projected the design of giving an English version of that poem. Accordingly, in 1771, he published the first book as a specimen; and quitting his residence at Oxford, he went to a farm-house at Forest Hill, where he pursued his design with unremitting assiduity till the year 1775, when the work was completed. It met with severe censure for the diffuseness of the translation, and for the unwarrantable liberties taken with the original. During the time that Mr Mickle was engaged in this work he supported himself entirely as a corrector of the press; and on his quitting that employment he had only the subscriptions which he received for his translation to support him.

A second edition of the *Lusiad* was prepared in 1778; and whilst he was meditating a publication of all his poems, he was appointed secretary to Governor Johnstone, who had obtained the command of the Romney. In November 1779 he arrived at Lisbon, and was appointed by his patron joint agent for the prizes which were taken. Mickle received much honour from the Portuguese, and was admitted a member of their Royal Academy. On his return to England he fixed his residence at Wheatley in Oxfordshire, and after writing several pieces in prose and verse, the last of which was a ballad called *Eskdale Braes*, he died on the 25th of October 1788. His poems possess but little general merit. The best of his ballads perhaps is *Cumnor Hall*, which suggested Scott's *Kenilworth*.

MICON, an Athenian artist and sculptor, was the son of Phanochus, and flourished in the fifth century B.C. He assisted in the painting of the Pœcile at Athens; and, according to some authors, had a hand in the famous picture of the "Battle of Marathon." He was assisted in some of his works by Polygnotus. He executed several statues; but he was especially famous for his representations of horses.

MICROMETER.

Micrometer, from *μικρος*, *small*, and *μετρον*, *a measure*, is the name of an instrument, generally applied to telescopes and microscopes, for measuring small angular distances within the field of the former, or the size of small objects within that of the latter.

Previously to the invention of the telescope astronomers experienced great difficulty in measuring small angles in the heavens; but we may safely infer from the observations of Hipparchus, that he had succeeded, either by the actual division of his instruments or by estimation, in determining celestial arcs to *one-third* of a degree.

When the telescope was applied by Galileo and our countryman Harriot to the examination of the solar spots, it does not appear that they executed their drawings from any other than estimated measures. This indeed seems quite certain in the case of Harriot, whose original sketches we have had an opportunity of inspecting. The elaborate solar observations of Scheiner, made in 1611, with a telescope on a polar axis, and published in 1630 in his *Rosa Ursina*, though minutely laid down and performed with great care, were certainly made without any instrument for subdividing the field of view.

Gascoigne. A.D. 1640.

As telescopic observations, however, multiplied, astronomers felt the necessity of having something more accurate than their eye for ascertaining minute distances in the heavens; and there can be no doubt that a micrometer was invented by our countryman Mr Gascoigne previous to 1640, not long after the publication of the *Rosa Ursina*. According to the description of it which he addressed in a letter to Mr Oughtred, and to the account of one of Gascoigne's own instruments which Dr Hooke examined, its construction was as follows:—A small cylinder, stretching across the eye-tube of the telescope, is cut into a fine screw throughout one-third of its length, the other two-thirds being formed into a coarser screw, with threads at twice the distance. This compound screw is confined at both ends to its place, the fine part of it passing through a female screw in one bar, and the coarse part through a female screw in another bar, these two bars being grooved into each other, as in a sliding rule. Hence, if a nicely ground edge is fixed to one bar and another to the other bar, so that these edges are accurately parallel, a motion of the screw round its axis will separate these two edges, and each edge will move with a different velocity. The parts of a revolution are measured by an index and divided face at the coarse end of the screw, while the number of whole revolutions is measured by a graduated bar moved by the coarse screw. The fine screw serves the purpose of keeping the middle part of this variable field (or the opening between the edges) in the axis or line of collimation of the telescope; for while the coarse screw moves the edge which it carries from the other edge considered as fixed, the fine screw moves both the edges, and indeed the whole frame, in an opposite direction, with one-half of the velocity; an effect which is produced by fixing its bar to the tube of the telescope.[1] As Mr Gascoigne fell in the civil wars, near York, in 1644, before he had given any full account of his invention and its application to astronomy, we are indebted to Mr Richard Townley, into whose hands one of the instruments came, for the preservation of so valuable a relic. Mr Townley informs us that Mr Gascoigne had made use of his micrometer for some years before the civil wars, and had measured distances on the earth, determined the diameters of the planets, and endeavoured to find the moon's distance from two observations of her horizontal and meridional diameters. Mr Townley's instrument was of the size and weight of "an ordinary pocket-watch." It marked 40,000 divisions in a foot, $2\frac{1}{2}$ divisions corresponding to a second of space. Mr Townley had it improved by a common watchmaker. Flamsteed was presented with one of the instruments in 1670 by Sir Jonas Moore; but though he left three guineas with Mr Collins to get proper glasses made for it, he could not procure them till autumn 1671, when he began his observations with it at Derby, and continued them with it in 1671, 1672, 1673, and 1674.[1] He informs us that Townley's improvement consisted in substituting one screw for two. He mentions also that Gascoigne had, in August 1640, measured with his micrometer the diameters of the sun and moon; and the relative distances of the stars in the Pleiades.

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[1] See *Phil. Trans.*, No. 29, p. 540, Nov. 1667; Lowthorp's *Abridgment*, vol. i., p. 226; and Costard's *History of Astronomy*.

Hooke.

Dr Hooke made an important improvement in this micrometer by substituting parallel *hairs* for the parallel edges of the brass plates;[2] and Dr Pearson conjectures that he had adopted this construction in his zenith sector, by which he proposed, in his dispute with Hevelius, to measure *single seconds.*

Malvasia. 1622.

It would appear, from the Ephemerides of the Marquis of Malvasia, published in the year 1662, that he had measured the distances of the stars, and the diameters of the planets, and projected the lunar spots, by means of a *reticle* of silver wire fixed in the focus of the eye-glass of his telescope. In order to determine the distances of the wires which composed this network, he turned it round till a star moved along one of the wires, and having counted the number of seconds which the star took to pass over the different distances between the wires, he obtained a very accurate scale for all micrometrical purposes.

Auzout. 1666.

About the year 1666 MM. Auzout and Picard, unacquainted with what had been done by Gascoigne, published an account of a micrometer.[3] Auzout's micrometer is said to have divided a foot into 24,000 or 30,000 parts. It resembled the Marquis of Malvasia's, with this difference, that the divisions were measured by a screw, and he sometimes employed fibres of silk in place of silver wires.

Huygens.

The celebrated Christian Huygens was also an early inventor of micrometrical methods; and the subject has been prosecuted with great diligence and success by Cassini, Röemer, Bradley, Savary, Bouguer, Dollond, Maskelyne, Ramsden, Sir W. Herschel, Rochon, Troughton, Wollaston, Arago, Fraunhofer, Pearson, Amici, Porro, and Secchi.

In giving an account of the inventions and methods of these various authors, we shall adopt the following arrangement:—

1. Description of wire-micrometers in which the wires are moved by one or more screws.
2. Description of wire-micrometers in which the angular distance of the wires is varied optically by changing the magnifying power of the telescope.
3. Description of double-image micrometers in which two singly-refracting lenses, semi-lenses, or prisms, are separated by screws.
4. Description of double-image micrometers in which the two images formed by two singly-refracting lenses, semi-lenses, or prisms, are separated optically.
5. Description of double-image micrometers in which the two images are formed by double refraction.
6. Description of position-micrometers.
7. Description of the lamp-micrometer and the lucid-disc micrometer.
8. Description of fixed micrometers with an invariable scale.
9. Description of micrometers for microscopes.

CHAP I.—DESCRIPTION OF WIRE-MICROMETERS IN WHICH THE WIRES ARE MOVED BY MEANS OF ONE OR MORE SCREWS.

Troughton's wire-micrometer.

The micrometer of Gascoigne, when furnished with hairs, as suggested by Dr Hooke, embodies the principle of the best and most recent micrometers. Instruments on this construction have been made by all our eminent opticians; but we have no hesitation in saying, that the micrometer constructed by the late celebrated artist Mr Troughton exhibits all the ingenuity which has been displayed in this delicate and useful apparatus. This eye-piece, and micrometer attached to it, are shown in figs. 1, 2, and 3, where fig. 1 is a horizontal section in the direction of the axis of the telescope. The eye-piece *ab* consists of two plano-convex lenses *a*, *b*, of nearly the same focal length, and the two convex sides facing each other. They are placed at a distance less than the focal length of *a*, so that the wires of the micrometer, which must be distinctly seen, are beyond *b*. This arrangement gives a *flat field*, and prevents any distortion of the object. This eye-piece slides into the tube *cd*, which screws into the brass ring *ef*, through two openings, in which the oblong frame *mn* passes. A brass circle *gh*, fixed to the telescope by the screw *i*, has rack-teeth on its circumference that receive the teeth of an endless screw *w* (fig. 3), which, being fixed by the arms *xx* to the oblong box *mn*, gives the latter and the eye-piece a motion of rotation round the axis of the telescope; and an index upon this box points out on the graduated circle *gh* (fig. 3) the angular motion of the eye-piece. The micrometer properly so called is shown in fig. 2, where *k*, *l* are two forks, each connected with a screw *o* and *p*, turned by the milled heads *m* and *n*. These forks are so fitted as to have no lateral shake. Two pins *q*, *r*, with spiral springs coiled round them, pass loosely through holes in the forks *k*, *l*, so that when the forks are pressed by their screws towards *q* and *r*, the spiral springs resist them, and consequently push them back when the screws are turned in the opposite direction.

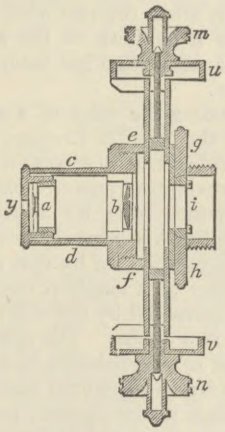

Fig. 1.

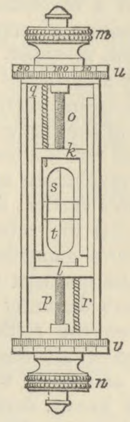

Fig. 2.

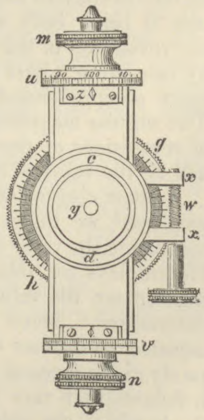

Fig. 3.

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[1] See Mr Baily's *Account of the Rev. John Flamsteed,* 1835, p. 24, 29, &c.

[2] Hooke's Posthumous Works, p. 497-8.

[3] *Phil. Trans.,* No. 21, p. 373, January 1666.

Wire-Micrometers.

Two fine hairs, or wires, or spiders' lines, *s*, *t*, are stretched across the forks, the one being fixed to the inner fork *k*, and the other to the outer fork *l*, so as to be perfectly parallel, and not to come in contact when they pass or eclipse one another, in which case they will appear as one line. A wire *st* is stretched across the centre of the field, perpendicular to the parallel wires.

The most difficult part of this instrument in the execution, as well as the most important, is the screw or screws which move the forks. The threads must not only be at the same distance, but have their inclination equal all round. In the screw used by Troughton, there are about 103·6 threads in an inch. On the right hand of the line *st* (fig. 2) is a scale, not seen in the figure, which indicates a complete revolution of either screw, the small round hole being the zero. This hole is bisected when the two lines appear as one.

In using this instrument we separate the wires by their respective screws till the object to be measured is exactly included between them. The number of revolutions and parts of a revolution necessary to bring the two wires into the position of zero will then be a measure of the angle required, provided the value of a revolution has been previously ascertained with accuracy.

Methods of finding the value of a revolution of the screw.

The easiest method of ascertaining the value of a revolution of the screw, according to the late Dr Pearson, who devoted much attention to this subject, is to ascertain how many revolutions and parts of a revolution measure exactly the sun's vertical diameter in summer, when his altitude is such that the refraction of both limbs is almost the same. The sun's diameter in seconds being divided by that number, the quotient will be the value of a single revolution, the sun's diameter having been corrected by the difference between the refraction of his two limbs. The ordinary method of ascertaining the value of a revolution is, to observe accurately the time taken by an equatorial star, or a star of known declination, reduced to the equator, to pass over the space between the wires when at a distance, and to convert this time into degrees, at the rate of 15° per hour. The number of degrees, minutes, and seconds, divided by the revolutions and parts of a revolution which are necessary to bring both wires into zero, will give the value of one revolution of the screw. The same thing may be done by measuring a base with great accuracy, and observing the space comprehended between the wires at that distance. The angular magnitude of this space, divided by the number of revolutions of the screws which bring the wires to zero, will be the value of each.

New method.

A most elegant and accurate method has been recently employed, we believe, by Professor Gauss of Göttingen, for measuring the value of the revolutions of micrometer-screws. He employs for this purpose a standard telescope with a micrometer, the value of whose scale has been accurately determined. Since the wires of a telescope-micrometer adjusted to distinct vision of the stars or planets are accurately in the focus of parallel rays falling on the object-glass, it follows that rays issuing from the wires, and falling on the inside of the object-glass, will emerge from it perfectly parallel. Now, if we place the object-glass of the standard telescope close or near to that of the first telescope, the parallel rays formed by those issuing from its wires will be refracted to the focus of the standard telescope, and a distinct image of the wires will be there formed. The observer, therefore, when he looks into the standard telescope, will see distinctly the wires of the first telescope, and, by means of his micrometer, he will be able to measure exactly the angular distance of these wires, at whatever distance they happen to be placed. This angular distance, divided by the revolutions and parts of a revolution which are necessary to bring the wires of the first telescope to the zero of their scale, will give the value of one revolution of the screw, or of one unit of the scale on the right hand of the long wire *st* (fig. 2).

Wire-Micrometers.

Fibres for micrometers.

The most essential parts of a micrometer are the parallel fibres, which require not only to be extremely fine, but of a uniform diameter throughout. Gascoigne, as we have seen, employed the edges of brass plates, Dr Hooke hairs, and subsequent astronomers wires and fibres of silk. Fontana in 1775 recommended the spider's line as a substitute for wires, and he is said (we think erroneously) to have obtained them so fine as the 8000th part of a line. Mr Troughton[1] had the merit of introducing the spider's line, which he found to be so fine, opaque, and elastic, as to answer all the purposes of practical astronomy. This distinguished artist, however, informed the writer of this article that it was only the stretcher, or the long line which sustains the web, which possesses these useful properties.[2] Sir David Brewster has employed the fibres of spun glass, which are bisected longitudinally with a fine transparent line about the $\frac{1}{3000}$th of an inch in diameter. This central line increases with the diameter of the fibre, and diminishes with the refractive power of the glass. In cases of emergency, the fibres of melted sealing-wax may be advantageously employed, or, as recommended by Professor Wallace, the fibres of asbestos. We have found crystals of *mesolite* so minute and regular as to be well adapted for the same purpose.

Wollaston's fine platinum wires.

The art of forming wire of extreme minuteness has been perfected by Dr Wollaston. Having placed a small platinum wire in the axis of a cylindrical mould, he poured melted silver into the mould, so that the platinum wire formed the axis of the silver cylinder. The silver was now drawn out in the usual way till its diameter was about the 300th of an inch, so that if the platinum wire was at first $\frac{1}{10}$th of the diameter of the silver cylinder, it will now be reduced to the 3000th part of an inch. The silver wire is now bent into the form of the letter U, and a hook being made at each of its ends, it is suspended by a gold wire in hot nitric acid. The silver is speedily dissolved by the acid, excepting at its ends, and the fine platinum wire which formed its axis remains untouched. In this way Dr Wollaston succeeded in forming wires $\frac{1}{4000}$th, $\frac{1}{5000}$th, and even $\frac{1}{18000}$th of an inch in diameter. When the fibres are prepared, their ends are placed in parallel scratches or grooves drawn on the forks, or, in other cases, on the diaphragm or field bar, and fixed by a layer of bees' wax or varnish, or, what is more secure, by pinching them with a small screw near their extremities.

Illumination of the wires.

In astronomical observations it is necessary to illuminate the wires of micrometers. In the transit instrument this is generally effected by means of a lamp, which throws its light along the horizontal axis of the telescope to a small speculum which reflects it upon the wire, although it may be done, as in other cases, by a small speculum placed outside of the object-glass. A very ingenious method has been more recently suggested and used, viz., of making the wires self-luminous by bringing them to a red heat by electricity. This idea seems to have presented itself to several astronomers,—to Arago, Savart, and Capocci of Naples; but it is to Arago that we are indebted for the earliest invention, construction, and use of it. The wire or wires, attached to suitable springs, pass from incandescence to absolute darkness, and reciprocally through all intermediate intensities. He had reason to fear that the images of objects beyond and apparently near to the heated wire would be sensibly undulating; but in an experiment which he made with a small power he found that there was no perceptible deviation to the extent of a second. This method of illumination has, we understand, been employed by Mr Johnson of Oxford in illuminating the wires of the microscopic micrometers for reading off the separation of the semi-lenses of the object-glass in his heliometer, without the observer leaving the telescopic eye-piece. He has used, we hear, the same process for illuminating the wires of his telescope micrometer. M. Arago has also employed galvanic electricity for bringing to a red heat a wire which is employed to illuminate the telescopic wires on their sides turned towards the observer, the useless rays which the wires do not stop, escaping by the object-glass, or being absorbed by the black varnish within the tube. The method of doing this in the best manner has been briefly described by M. Breguet in the *Comptes Rendus*, &c., 1847, vol. xxiv., p. 322. It consists in making a transverse slit in the tube which contains the eye-glass, and placing the illuminating wire without the tube, and in a plane between the eye-glass and the wires to be illuminated.

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[1] Mr Quekett ascribes the introduction of the cob-web micrometer to Ramsden. (*Treatise on Miscroscope*, p. 196.)

[2] Captain Maury, superintendent of the National Observatory in the United States, informs us that when in search of spider lines for the diaphragm of his telescopes, he procured the finest and best threads from a cocoon of a mud-red colour; but he adds, the threads of this cocoon, as seen singly in the diaphragm, were of a golden colour. (*Physical Geography of the Sea*, p. 121.)

M. Porro's method of illumination. Another method of illuminating the wires has been imagined by M. Porro. It consists in substituting plates of glass instead of the metallic plates which carry the wires. These plates of glass are ground and polished on their edge into suitable curves, so as to introduce, perpendicularly to the axis of the telescope, a thin vein of light, which will illuminate the wires without reaching the eye of the observer. Hence it happens that the wires appear of a silvery white in a dark field.[1]

Images of wires proposed. Many years ago Sir David Brewster communicated to the Chevalier Burg, the distinguished author of the Lunar Tables, a new method of obtaining micrometer lines by placing in the field of view the reflected images of a fixed or moveable system of wires, or of lucid discs attached to the side of the eye-piece. This is effected by placing in the field of view a plate of parallel glass inclined to the axis of the eye-piece. The wires being illuminated, their images will be distinctly seen in the field of view, and while they have all the properties of real wires, they have the additional advantage of being transparent, so that a star or small planet or satellite may be seen moving along the axis of the wire, in place of being eclipsed by it. The motions of the wires in real micrometers are accurately repeated in its reflected image, and consequently the position and distance of the image-wires are measured with the same accuracy as if they were real.

Photographic micrometers. A new method of constructing microscopical scales or systems of delicate lines, opaque or transparent, and fitted both for astronomical and microscopical observations, has been recently proposed by Sir David Brewster. Mr Dancer of Manchester has succeeded in making photographic portraits upon collodion so small that they are wholly invisible to the eye, and that *ten thousand* portraits may be introduced into a square inch. The film of collodion upon which these photographs are taken is so thin and transparent that it is invisible, and allows objects to be seen through it as distinctly as if it were the thinnest glass. If a system of opaque or transparent lines therefore is impressed upon it photographically, when reduced to the minutest size from a system of large and sharply defined lines, we shall have the most perfect micrometrical scale that can be conceived, the portion of the collodion that contains no nitrate of silver being as transparent as if the dark spaces were solid wires or metallic plates placed in the focus of the eye-glass. (See chapters vi., p. 118, and viii., p. 121, for an account of other applications of this method.)

For a great deal of valuable practical information respecting the construction and use of the wire-micrometer, the reader is referred to Dr Pearson's *Introduction to Practical Astronomy* (vol. ii., pp. 99, 110, 115, &c.), where valuable tables will be found for facilitating the application of the micrometer both to celestial and terrestrial purposes. See also Sir John Herschel and Sir James South's *Observations of* 380 *Double and Triple Stars* (p. 22, 23), containing tables of the values of Troughton's screws.

CHAP. II.—DESCRIPTION OF WIRE-MICROMETERS IN WHICH THE ANGULAR DISTANCE OF THE WIRES IS VARIED OPTICALLY BY CHANGING THE MAGNIFYING POWER OF THE TELESCOPE.

Röemer. MM. Röemer and De la Hire first conceived the idea of varying the angular magnitude of the meshes of a net of silver wire fixed in the focus of the eye-glass of a telescope, for the purpose of measuring the digits of eclipses. This was done by a second lens moving between the wires and the object-glass. The late Mr Watt informed the writer of this article that he had used a similar principle, but had never published any account of it.

The plan of opening and shutting a *pair of parallel wires* optically instead of mechanically, and of using it as a general principle in micrometers, was first adopted by Sir David Brewster, and has been applied to a variety of methods of varying the magnifying power of the telescope.

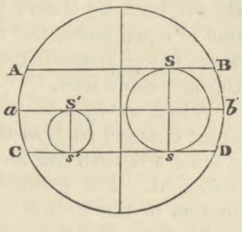

Fig. 4.

The general principle will be readily understood from fig. 4, where AB, CD are two wires or lines of any kind permanently fixed in the focus of the eye-glass of a telescope. If the sun S′s′ is in contact with the lower wire CD, it is obvious, that if we increase the magnifying power of the telescope by any optical means anterior to the wires, we may magnify or expand the sun's disc S′s′ till it becomes Ss, when its north or upper limb will exactly touch the upper wire AB. Now if the sun's diameter happens to be 31′ when its disc Ss just fills the space between the wires AB, CD, the distance of the wires must have been 62′ when, as at S′s′, it fills only half that space. Hence the wires have been moved optically, so to speak, and have subtended all angles between 31′ and 62′.

The methods of varying the magnifying power of the telescope used by Sir David Brewster consist in varying the distance of the two parts of the achromatic eye-piece; or in varying the focal length of the principal object-glass by means of another object-glass, either convex or concave, moving between it and its principal focus.

Eye-glass micrometer. The first of these methods is shown in fig. 5, where AB

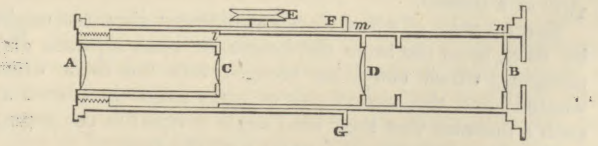

Fig. 5.

is the eye-piece with its four lenses, A, C, D, B, in their natural position. The part AFG, with the two lenses A, C, is fixed to the telescope, and a space is left between the tube AC and the outer tube AFG, to allow the moveable part DB of the eye-piece to get sufficiently near the lens C. The tube DB is moved out and in by a rack and pinion E. A scale is formed on the upper surface *mn*, and subdivided in the usual manner with a lens and vernier, which it is unnecessary to represent in the figure. The value of the divisions of the scale are determined by direct experiment. A motion of DB through a space of 4 inches will, generally speaking, double the magnifying power of the telescope.

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[1] *Comptes Rendus*, &c., 1851, vol. xxxii., p. 677.

Object-glass micrometer.

The best method, however, of varying the magnifying power of the telescope is the second, which is shown in fig. 6, where O is the object-glass, f its principal focus, and L the second lens, which is moveable between O and f. Parallel rays R, R, after being refracted by O, so that they would converge to f, are intercepted by L, which converges them to F, the focus of the combined lenses. The effect of the lens L is therefore to diminish the focal length of the object-glass, and consequently the magnifying power of the telescope, which will obviously be a *minimum* when the lens L is at l, and a *maximum* when it is at l'. The angle subtended by a pair of fixed wires will suffer an opposite change to that on the magnifying power, being a maximum when the lens L is at l, and a minimum when it is at l'. Hence the scale for measuring the variable angle of these wires may always be equal to the *focal length* of the object-glass O; and the inventor of the instrument has shown, both by theory and by experiment, that the scale is one of equal parts, the variations in the angle of the fixed wires being proportional to the variations in the position of the moveable lens.

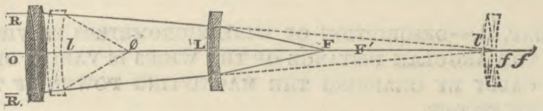

Fig. 6.

When we wish to measure angles that do not suffer a great change, such as the diameters of the sun and moon, a scale less than the focal length of the object-glass will be sufficient. For example, if we take a lens L, which by a motion of ten inches varies the magnifying power from 40 to 35, then, if the angle of the wires is 29′ when the lens L is at l', it will be 39′ 9″ when the lens is ten inches from l', or the magnifying power 35. We have therefore a scale of *ten* inches to measure a change of angle of 4′ 9″, so that every 10th of an inch will correspond to 3″·3, and every 100th of an inch to ⅓d of a second. Such a micrometer will serve to measure the diameters of the sun and moon at their various distances from the earth.

If we wish to measure the distances of some double stars, or the diameters of some of the smaller planets, with a telescope whose magnifying power varies from 300 to 240, by the motion of a lens over *ten inches*, place the parallel wires at a distance of 40″, which will be increased to 50″ by the motion of the lens. Hence we have a scale of *ten inches* to measure *ten seconds*, or the *tenth* of an inch to measure *one* second, or the 100th of an inch to measure $\frac{1}{10}$th of a second.

Several pairs of wires, placed at different distances, might be fixed upon the same diaphragm, or upon separate diaphragms, which could be brought into the focus when wanted; and the second pair of wires might be placed at such a distance that their least angle is equal to the largest angle of the first pair, and so on with the rest.

A wire-micrometer thus constructed is certainly free from almost all the sources of error which affect the common moveable wire-micrometer. The errors arising from the imperfection of the screw, the uncertainty of zero, and other causes, are avoided; and the wires are always equidistant from the centre of the field, so as to be equally affected by any optical imperfection in the telescope. The scale indeed may be formed by direct experiment, and the results will be as free from error as the experiments by which the scale is made.

When this micrometer is applied to a portable telescope it becomes of great use in naval, military, or geodetical operations, and is employed in measuring distances, either by taking the angle subtended by a body of known dimensions, or by measuring the two angles subtended by a body of unknown dimensions from the two extremities of a known or measured base. For these purposes the telescope is fitted up without a stand, as shown in fig. 7.

The principle of separating a pair of wires optically is singularly applicable to the Gregorian and Cassegrainian telescopes, where no additional lens or mirror is required. As the magnifying power of both these telescopes may be increased merely by increasing the distance of the eye-piece from the great speculum, and then readjusting the small speculum to distinct vision, we can thus vary the angle of a pair of fixed wires by making the eye-piece moveable. This will be easily comprehended from Figure 8, where SS is the great speculum of a Gregorian reflector, AA the tube, M the small speculum, whose focus is G, and centre of curvature H. It is fixed to an arm MQ, moveable to and from SS in the usual way. The image $R'r'$ is that formed by the speculum SS, and $r''R''$ that formed by the small speculum. This last image being in the focus of the eye-glass E, will be seen distinct and magnified. If the eye-glass E is pulled out to E′, then, in order that the object may be seen distinctly, the image $r''R''$ must be brought into the position $r'''R'''$, FF′ being equal to EE′; but this can be done only by advancing the small speculum M to M′, f and F′ being now the conjugate foci of M. But by this process the magnifying power has been considerably increased, because the part of the whole magnifying power produced by M was equal to $\frac{MF}{Mf}$, whereas it is now $\frac{M'F'}{M'f}$, a much larger quantity. The angle subtended by the wires has therefore been diminished in the same proportion as the magnifying power has been increased. The scale in this case is not one of equal parts, but after the extreme points of it have been determined experimentally, the rest may be filled up either by calculation or direct experiment.

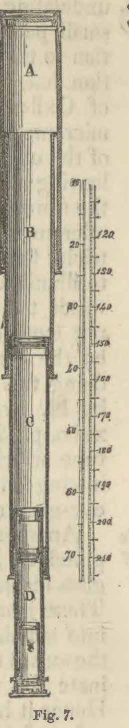

Fig. 7.

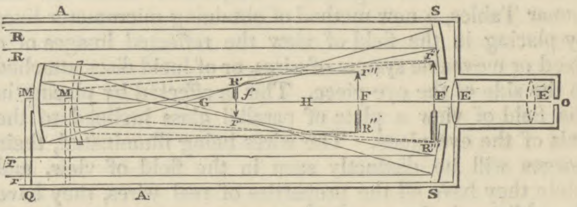

Fig. 8.

Dr Pearson[1] has inadvertently stated that Sir David Brewster's "patent micrometer is not competent to measure very small angles, even if it had sufficient magnifying power." If he means the patent micrometer as made by Mr Harris, as a naval and military telescope for measuring distances, or as a coming-up glass, he is quite right, because the power of measuring small angles is not required for these practical purposes. But it is quite evident that the *smallest* angles can be measured by the micrometer when fitted up for astronomical purposes. We have only to use a pair of wires placed at a very small distance, or a pair of semi-lenses whose centres are placed at a very small distance, and then vary their angle till it becomes equal to the very small angle which we wish to measure.

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[1] *Introduction to Practical Astronomy*, vol. ii.

CHAP. III.—DESCRIPTION OF DOUBLE-IMAGE MICROMETERS IN WHICH TWO SINGLY-REFRACTING LENSES, SEMI-LENSES, OR PRISMS, ARE SEPARATED BY SCREWS.

Röemer, 1678.

M. Röemer, the celebrated Danish astronomer, is said to have been the first who suggested the use of a double-image micrometer. He did this about 1678, but the idea does not seem to have been carried into effect, or known to his successors. Nearly seventy years afterwards, viz., in 1743, Mr Servington Savary of Exeter communicated to the Royal Society an account of a double-image micrometer; and five years afterwards, in 1748, the celebrated Bouguer proposed the very same construction, which he called a heliometer. This instrument consisted of two lenses, which could be separated and made to approach each other by a screw or other mechanical means. These lenses gave double images of every object; and when the two images of any object, such as the sun or moon, were separated till they exactly touched one another, the distance of the object-glasses afforded a measure of the solar or lunar diameter, after an experimental value of the divisions of the scale had been obtained.

Savary. 1743.

Bouguer. 1748.

Dollond. 1753.

As two complete lenses, however, must always have their least distance equal to the diameter of either, this instrument was incapable of measuring the diameters of small bodies. This obvious defect no doubt led John Dollond, in 1753, to the happy idea of the divided object-glass micrometer, in which the two halves of an object-glass are made to recede from the position in which they form a complete object-glass. When the centres of the two halves coincide, they obviously form one lens, and give only one image. When the centres are slightly separated, the images will be slightly separated; and small objects may be brought into contact and have the angles which they subtend accurately measured. The scale will therefore have a zero corresponding to the coincidence of the centres of the semi-lenses. The principle of this instrument will be understood from fig. 9, where H, E are two semi-lenses, whose centres are at H, E, and F their focus. If PQ be a circular object whose diameter is to be measured, or P, Q two points whose angular distance is to be determined, the lenses are to be separated till the two images x, z are in contact at F. As the rays QHF, PEF pass unrefracted through the centres H, E of the semi-lenses, the angle subtended by QP will be equal to the angle HFE, or that which the distance of the centres of the semi-lenses subtends at F. Since the angles, therefore, are very small, they will vary as HE; and when the angles corresponding to any one distance of the centres is determined, those for any other distance will be ascertained by simple proportion.

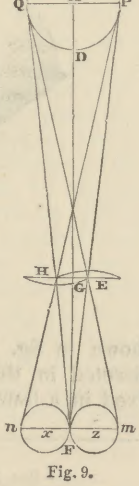

Fig. 9.

Mr Dollond, who had not at this time invented the achromatic telescope, applied his micrometer to the object end of a reflecting telescope, as shown in fig. 10, which represents the micrometer as seen from beyond the object end of the reflector. A piece of tube B, carrying the micrometer, slides into or over the tube A of the telescope, and is fastened to it by a screw. The tube B carries a wheel (not seen in the figure) formed of a ring racked at the outer edge, and fixed to the brass plate CC, so that a pinion moved by the handle D may turn it into any position. Two plates F, G are kept close to the plate CC by the rabbeted bars H, H, but with so much play that they can move in contrary directions by turning the handle E, which drives a concealed pinion that works in the two racks seen in the highest part of the figure. As the two semi-lenses are fixed to the plates F, G, their centres will be separated by the action of the handle E, and their degree of separation is measured by a scale of 5 inches subdivided into 20ths of an inch, and read off by a vernier on the plate F, divided into 25 parts, corresponding to 24 of the scale, so that we can measure the separation of the semi-lenses to the $\frac{1}{500}$th of an inch. The vernier is to the right of H, and may be adjusted to the zero of the scale, or the position of the lenses when they give only one image, by means of the thumb-screw I, a motion of the vernier being permitted by the screws which fix it to the plate F passing through oblong holes.[1]

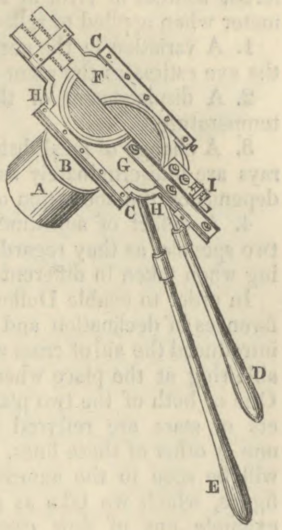

Fig. 10.

Mosotti.

In this construction the micrometer is too far from the observer, and destroys the equilibrium of the telescope. The instrument itself, however, has more serious defects, as it has been found that the measures of the sun's diameter, taken by different observers with the same instrument and at the same time, differ so much as 12 or 15 seconds. This defect has been ascribed to the different states of the observers' eyes, according as they have a tendency to give distinct vision within or beyond the focal point, where the image is most perfect; in the former case the limbs being somewhat separated, and in the latter overlapping. M. Mosotti, in the *Effemeride* of Milan for 1821, has discovered the true cause of this defect by a series of accurate experiments, which he made with this micrometer attached to a Gregorian reflector of two feet in focal length. The focal length of the divided object-glass was 511·3357 inches, or 42 feet 7½ inches. M. Mosotti has shown that a diversity of measures will be obtained by the same observer, if, for the purpose of obtaining distinct vision, he gives a slight displacement to the small speculum by the adjusting screw. If the position of this speculum which gives distinct vision were a point, it would be easy to find that point; but as distinct vision can be obtained only within a space of 10 or 12 thousandths of an inch, owing to aberration, every different observer will place the mirror at a different point within that range, and consequently obtain a measure corresponding to the image which he views. M. Mosotti recommends that the axis of the adjusting screw, which carries the small speculum, should carry a vernier connected with a scale on the outer surface of the tube A. By means of this vernier the observer is able to give a fixed position to the small speculum, so that he always views the same image, and is thus sure of obtaining the same measure of the same object, so far as the observation is concerned. M. Mosotti found also that the measures were affected by a change of temperature, which, by changing the length of the tube, displaced the small speculum. In his instrument this displacement amounted to 0·0075 of an inch, which, he has shown, corresponds to a change of focal length from 511·3357 to 514·84 inches; and that the error from this cause, upon a length of 30′, will be 13″ in excess.

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[1] *Phil. Trans.*, vol. xlviii.

Pearson. The following is Dr Pearson's enumeration of the different sources of error in the divided object-glass micrometer when applied to reflectors:—

1. A variation in the position of the small mirror when the eye estimates the point of distinct vision.

2. A displacement of the small mirror by change of temperature.

3. A change of focal distance when central and extreme rays are indiscriminately used. The amount of this error depends on the aberration of the semi-lenses.

4. A defect of adjustment, or of perfect figure, in the two specula, as they regard each other, the measures varying when taken in different directions.

Maskelyne. In order to enable Dollond's micrometer to measure differences of declination and right ascension, Dr Maskelyne introduced the aid of cross wires, which he fixed in a moveable ring at the place where the double image is formed. One or both of the two planets or stars are referred to one or other of these lines, as will be seen in the annexed figure, which we take as an example out of four cases. Let ENWS be the field of view, NS the meridian, and EW the line of east and west; then, in order to obtain the difference of right ascension and declination of two stars, he opened the semi-lenses till he obtained double images of each star. He then turned round the micrometer till the two images of the first star passed over the vertical wire NS at the same instant, and having counted the time that elapsed till the two images of the other star passed over the same line, he had the difference of right ascension in time. By means of the screw which elevated his telescope, and partly by opening the semi-lenses, he made the north image of one star, and the south image of the other, as at A, B, describe in their motion the horizontal wire EW, and at that position of the semi-lenses the scale indicated the difference of declination.

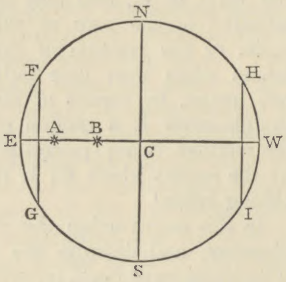

Fig. 11.

Mr Dollond junior's improvement. A very important improvement upon the divided object-glass micrometer was made by Mr Dollond's son, who adapted it to a refracting telescope, and removed the different sources of error to which it had been found liable. This improvement consists both in the *nature, form,* and *position* of the semi-lenses. The semi-lenses are made concave, and consist of crown and flint glass, so as to give an achromatic image along with the object-glass of the telescope to which they are applied. These concave semi-lenses, of course, lengthen the focal distance of that object-glass. When a *circular* lens was bisected, as in the old construction, the metallic parts which held the semi-lenses obstructed the light in proportion to their separation; a defect of a serious nature in an instrument. In order to correct this evil, Mr J. Dollond substituted two long slices of glass cut from the diametral portion of a lens nearly six inches in diameter. Hence, in every position of these oblong semi-lenses, none of the metallic setting comes before the object-glass, and consequently the light is never obstructed, and is always of the same amount, whatever be the separation of the lenses. In the old construction, where the diameters of each lens slid along each other in contact, a part of the central portions having been removed by grinding the diameters smooth, the two images of an object never could coincide so as to give an accurate *zero;* but in the new construction, the space equal to what was removed by grinding is filled up with a brass scale and vernier; and the only evil of this is the loss of light corresponding to the thickness of this scale; but this trifling defect is amply compensated by the perfect coincidence of the images at *zero.*

This important instrument is shown in fig. 12, where the same letters are used as in fig. 10 to denote the analogous parts of the two instruments. The end of the telescope is shown at A, and B is the rim of brass, which, by sliding upon A, fixes the micrometer to the telescope. The frame CC, moved by teeth on its outer edge, carries one of the halves G of the lens, and a similar frame with teeth carries the other half F. A scale six inches long is fastened like an edge-bar to CC, and each inch is subdivided into 20 parts, which are read off with a vernier of 25 parts, which is fastened as an edge-bar to the moveable frame that carries F. The two moveable frames are imbedded in a fixed plate HH, screwed to the tube B of the micrometer, and having a circular hole in its middle equal to the diameter of the object-glass. The two semi-lenses are separated by turning the milled head to the right of A, which moves the frame CC, and then the other frame F through the medium of a concealed wheel and a concealed pinion. The mechanism for giving the rotatory motion is also concealed. The adjustment of the vernier to zero is effected by the screw I.

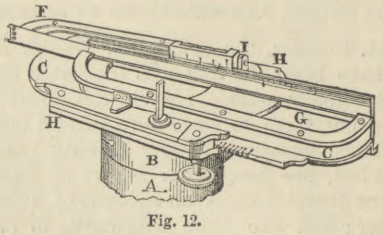

Fig. 12.

Ramsden's dioptric micrometer. 1777. The property which the double-image micrometer possesses of measuring angles in all directions, directed to it the attention of Ramsden and other eminent opticians. Ramsden accordingly communicated to the Royal Society of London in 1777[1] an account of two instruments of this kind, under the name of the *Dioptric* and *Catoptric* Micrometers. In order to avoid the effects of aberration, Ramsden proposed, in his dioptric micrometer, to place two semi-lenses in the conjugate focus of the innermost lens of the erect eye-tube of a refracting telescope. In place of the imperfections of the lenses being magnified by the whole power of the telescope, they are magnified only about five or six times, and the size of the micrometer glass does not require to be $\frac{1}{100}$th part of the area which is necessary in Dollond's instrument. This instrument is shown in fig. 13, where A is a convex or concave lens, bisected in the usual way. One of the semi-lenses is fixed in a frame B, and the other in a similar frame E,

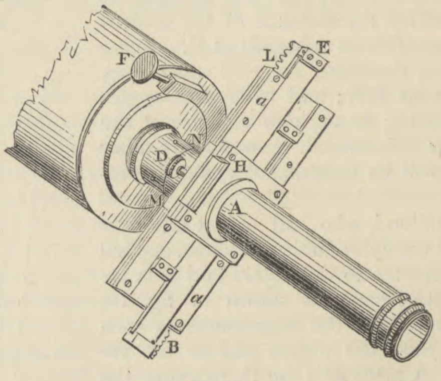

Fig. 13.

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[1] See *Phil. Trans.*, vol. lxix., 1779, p. 419.

Double-Image Micrometers.

both of which slide upon a plate H, against which they are pressed by thin plates *a*, *a*. The milled button D, by means of a pinion and rack, moves these frames in opposite directions; and the separation of the semi-lenses thus effected is measured by a scale of equal parts L on the frame B, the zero being in the middle, and the divisions read off by two verniers at M and N, carried by the frame E; the vernier M showing the relative motion of the two frames when the frame B moves to the right, and N when the frame B is moved to the left. An endless screw F gives the whole micrometer a motion round the axis of vision. This instrument being only the divided object-glass micrometer in miniature, and differently placed, the reader will have no difficulty in understanding its construction and use, from the details already given in the preceding pages.

Dr Pearson informs us, on the authority of Mr Troughton, that a Captain Countess, R.N., having accidentally broken the third lens of a terrestrial eye-piece of his telescope, observed the double images which it produced; and that this observation led to the contrivance of the coming-up glass that was first made by Nairne, with a double screw for separating the halves of the amplifying lens. Hence it is *conjectured* that Ramsden derived his idea of using a bisected lens for his dioptric micrometer and dynameter. The above facts may be quite true; but Ramsden certainly did not require any such hint, as it was a very natural transition from a bisected object-glass to a bisected eye-glass.

Dr Pearson also states that Mr George Dollond had constructed a dioptric micrometer almost the same as Ramsden's, without knowing anything of what Ramsden had proposed. We have no doubt that both these ingenious opticians were quite original in their ideas, for it will not be supposed that Captain Countess's broken lens furnished Mr Dollond with the idea of his contrivance. Dr Pearson has given a drawing and description of Mr Dollond's construction of the micrometer as made for Mr Davies Gilbert and himself.[1] It does not appear that Mr Ramsden ever constructed it. The weight of this micrometer was found by Dr Pearson too great for an ordinary achromatic telescope.

Ramsden's catoptric micrometer.

Mr Ramsden likewise proposed a catoptric double-image micrometer, which, from being founded on the principle of reflection, is not disturbed by the heterogeneity of light, while he considered it as "avoiding every defect of other micrometers," having "no aberration, nor any defect which arises from the imperfection of materials or of execution, as the extreme simplicity of its construction requires no additional mirrors or glasses to those required for the telescope." "It has also peculiar to itself the advantages of an adjustment to make the images coincide in a direction perpendicular to that of their motion. In order to effect these objects, Mr Ramsden divided the small speculum of a Cassegrainian reflector into two equal halves, and by inclining each half on an axis at right angles to the plane that separated them he obtained two distinct images; but as their angular separation was only half the inclination of the specula, which would give only a small scale, he rejected this first idea, and separated the semi-specula by making them turn on their centre of curvature, any extent of scale being obtained by fixing the centre of motion at a proportional distance from the common centre of curvature. The mechanism necessary to effect this is shown in fig. 14, where A is the bisected speculum, one of the semi-specula being fixed on the inner end of the arm B, its outer end being fixed on a steel axis *x* extending across the mouth of the tube C. The other semi-speculum is fixed on the inner end of the arm D, its outer end terminating in a socket *y*, which turns upon the steel axis *x*. These arms are braced by the bars *a*, *a*. A compound screw G, having its upper part cut into double the number of threads in an inch, viz., 100, to the lower part *g*, which has only 50, works with the handle in a nut F in the side of the tube, while the part *g* turns in a nut H fixed to the arm B. The point of the compound screw separates the ends of the arms B and D, and pressing against the stud *h* fixed to the arm D, turns in the nut H on the arm B. A spiral spring within the part *n* presses the two arms B, D against the direction of the double screw *e g*, so as to prevent all shake or play in the nut H. The progressive motion of the screw through the nut will be half the distance of the semi-specula, so that these specula will be moved equally in opposite directions from the axis of the telescope.

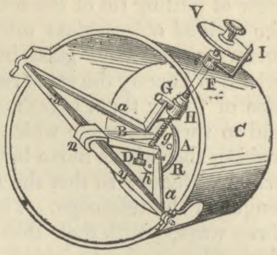

Fig. 14.

A graduated circle V, divided into 100 parts on its cylindrical surface, is fixed on the upper end of the screw G so as to cause it to separate the semi-specula. The fixed index I shows the parts of a revolution performed by the screw, while the number of whole revolutions of the screw is shown by the divisions of the same index. A steel screw R, moveable by a key, inclines the small speculum at right angles to the direction of its motion. Distinct vision is procured in the usual manner, and the telescope has a motion about its axis, in order to measure the diameter of a planet in any direction; and the angle of rotation in reference to the horizon is shown by a level, graduated circle, and vernier, at the eye end of the large tube.

Catoptric micrometer for a Newtonian telescope.

A catoptric double-image micrometer has been suggested by Sir David Brewster as applicable to the Newtonian telescope. The plane mirror is bisected, and is made to form two images, either by giving each semi-speculum a motion round their common line of junction, or round a line perpendicular to that common line. The mechanism by which this may be effected does not require any description. If the micrometer is required for the sun or any luminous body, the small mirror may be made of parallel glass, which would have the advantage of not obstructing any of the light which enters the telescope, while it reflects enough for the purposes of distinct vision. We shall again have occasion to refer more particularly to this idea in the next section.

Amici's micrometer.

Professor Amici has described, in the Memoirs of the Italian Society, a new micrometer, which gives double images by means of semi-lenses separated by mechanical means; but as we have not access to this work, we shall draw our description of the instrument from one given by Dr Pearson, which is very far from being distinct, in so far, at least, as the construction of the semi-lenses, or *bars of glass*, as they are called, are concerned. The semi-lenses seem to be portions of a large concave lens, separated in the usual manner, so as to give two distinct images of objects; but the peculiarity of the invention seems to consist in the lenses being placed between the object-glass of a telescope and its principal focus, the cone of rays being divided at a point about six inches before the place where the focal image is formed. Dr Pearson, who made experiments with one of these instruments, has hinted at the inconveniences which he experienced in using it.

CHAP. IV.—DESCRIPTION OF DOUBLE-IMAGE MICROMETERS IN WHICH THE TWO IMAGES FORMED BY TWO SINGLY-REFRACTING LENSES, SEMI-LENSES, OR PRISMS, ARE SEPARATED OPTICALLY.

In the year 1776 Dr Maskelyne constructed and used

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[1] *Introduction to Practical Astronomy*, vol. ii., p. 182.

Double-Image Micrometers.

Maskelyne's prismatic micrometer.

his prismatic micrometer, which he had contrived with the view of getting rid of the sources of error to which he found the divided object-glass micrometer liable. Having cut a prism or wedge of glass into two parts, so as to form two prisms of exactly the same refracting angle, he conceived the idea of fixing them together, so as to produce two images, and to vary the angle which these two images formed by making the prisms move between the object-glass and its principal focus; so that the scale is equal to the whole focal length of the telescope. The two prisms may be placed in three ways,—with their thin edges joined, with their square thick edges or backs joined, or with their sides or triangular edges joined. In the first position the double images will have only one-half of the light which is incident on the object-lens when the prisms are close to it, and their degree of illumination will diminish as they approach the focus. In the second position they will, as before, have only one-half of the incident light when close to the object-glass, but the illumination will gradually increase as the prisms advance to the focus. In the third case, the prisms being in a reverse position, the light will be the same in every part of the scale, each of them receiving half the rays which fall upon the object-glass. On this account Dr Maskelyne preferred this last arrangement.

In the instrument which Dr Maskelyne constructed, and which seemed to have had only a thirty-inch object-glass, the prisms were not achromatic, and consequently the touching limbs of a luminous body were affected with the prismatic colours. In the case of the sun, where all the rays might have been absorbed but the red, this was of little consequence; but in other cases it was a serious defect, which could be removed only by making the prisms achromatic; or it might have been diminished by making the prisms of fluor spar, in which the dispersion is very small. One of the Dollonds accordingly executed for Dr Maskelyne an achromatic prism, which performed well. It does not appear that Dr Maskelyne made any observations of value with this instrument.

New divided object-glass micrometer.

A new divided object-glass micrometer has been constructed by Sir David Brewster, and described in his Treatise on New Philosophical Instruments. It consists of an achromatic object-glass LL (fig. 15), between which and its principal focus *f* two achromatic semi-lenses, fixed at a given distance, are made to move. These lenses are shown in fig. 16, and are fixed on a piece of tube, which screws into a tube, by pulling out and pushing in which they are made to recede from or approach to the object-glass LL. By this motion the angle subtended by the two images varies in the same manner as the angle subtended by a pair of fixed wires was made to vary by the motion of a second object-glass. When the semi-lenses are close to LL, as shown at A, B (fig. 15), the two images which they form are much separated, and their centres subtend a large angle; but as the lenses approach to *f*, the centres of the images gradually approach each other, and consequently the angle which they subtend continually increases. Hence, if we determine by experiment the angular distance of their centres when the lenses are close to LL, and likewise the angle when they are at *f*, the other end of the scale, and if we fill up the intermediate points of the scale either from theory or direct experiment, we shall have an instrument which will measure with the greatest accuracy all angles between the two extreme ones. Another or several pairs of semi-lenses may be applied to the same telescope, and placed at smaller or greater distances, so that, by means of other scales adapted to them, we may obtain all angles that may be required. The lenses A, B may be concave or convex; and when a large scale is required, with a tenth of an inch to a second, or even greater, we have only to use semi-lenses of long foci, and the scale may be confined to the part of the tube nearest the focal point.

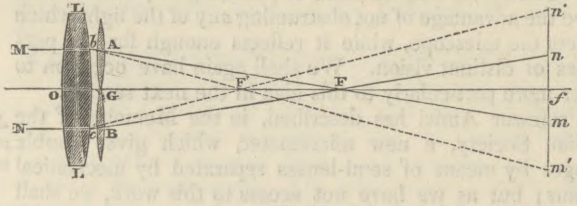

Fig. 15.

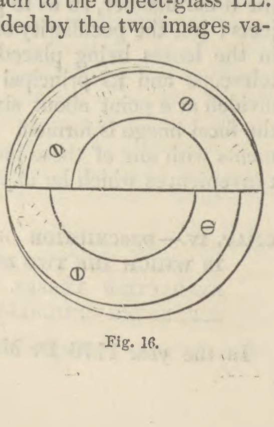

Fig. 16.

Sir David Brewster has proved, both from theory and experiment, that the scale is one of equal parts; so that, after having ascertained experimentally the two extreme angles, the whole scales may be completed by dividing the interval into any number of equal parts, and these subdivided, if necessary, by a vernier scale.

When the semi-lenses are placed without the object-glass LL, and this object-glass moved towards *f*, as in the annexed figure, the angular distance of the images is invariable.

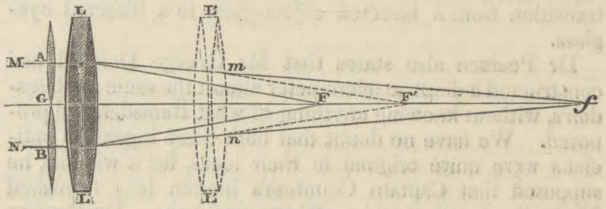

Fig. 17.

This instrument has been constructed for measuring distances, and as a coming-up glass for ascertaining whether a ship is approaching to or receding from the observer. In this form it constitutes part of fig. 7, the semi-lenses being made to screw into the same place as the second object-glass, and having a separate scale for themselves. In this form many of the instruments have been constructed by Tulley.

Prismatic micrometer for Newtonian reflectors.

Among the optical micrometers we may describe another invented by Sir David Brewster, and adapted solely to the Newtonian telescope. In order to get rid of the loss of light by the reflection of the small plane speculum, he uses an achromatic prism to reflect the light just as much out of the axis of the telescope as will allow the head of the observer to be applied to the eye-tube, without obstructing any of the light which enters the tube. By using two prisms, as in Maskelyne's instrument, and moving them along the axis of his telescope through a small distance, we shall obtain a good micrometer. The prisms may be separated mechanically, or a doubly-refracting prism may be fixed upon the face of the single or achromatic prism used to turn aside the rays. The achromatism of a single glass prism may be corrected by the doubly-refracting prism, a balance of refraction being left sufficient to turn aside the image to the observer's eye.

CHAP. V.—DESCRIPTION OF DOUBLE-IMAGE MICROMETERS IN WHICH THE TWO IMAGES ARE FORMED BY DOUBLE REFRACTION.

Rochon's first micrometer.

The happy idea of applying the two images formed by double refraction to the construction of a micrometer unquestionably belongs to the Abbé Rochon; and though Dr

Double-Image Micrometers.

Pearson has laboured to show that Dr Maskelyne's prismatic telescope was constructed before Rochon's, yet this does not in the smallest degree take away from the originality and priority of Rochon's invention; for the idea of varying the angle by the motion of the prisms can scarcely be viewed as an essential part of the invention.

Although the double refraction of rock-crystal is small, yet, from its limpidity and hardness, the Abbé Rochon regarded it as superior to any other substance for making doubly-refracting prisms. When he used one prism so cut that its refracting edge coincided with the axis of the prism, in which case its double refraction was the greatest, he found that the separation of the two images was too small to give the angles which he required.[1] He therefore fell upon a most ingenious plan of doubling the amount of the double refraction of one prism, by using two prisms of rock-crystal, so cut out of the solid as to give each the same quantity of double refraction, and yet to double that quantity in the effect produced. The construction of the compound prism was so difficult that M. Rochon informs us that "he knew only one person, M. Narci, who was capable of giving rock-crystal the prismatic form in the proper direction for obtaining the double refractions necessary to the goodness of the micrometer." The method used by Narci seems to have been kept a secret; for in 1819 Dr Wollaston set himself to discover the method of constructing these compound prisms, and has described it in the *Philosophical Transactions*,[2] but not in such a manner as to be very intelligible to those who are not familiar with such subjects. We conceive that the process may be easily understood from the following rule:—Cut a hexagonal prism of quartz into two halves by a plane passing through or parallel to its axis. Grind and polish the two cut faces, and by means of Canada balsam cement the one upon the other, so that any line or edge in the one face may be perpendicular to the same line in the other. Cut and polish a face on each of the united portions, so that the common section of these faces with the cemented planes may be parallel to the axis of the crystal, while they are equally inclined to these planes, and the prism will be completed.

Method of cutting the prisms from the crystal.

We shall now explain, by a diagram, a more simple and economical way of cutting these prisms, though the principle is exactly the same. Let AKGDBLHF be half of a hexagonal prism of quartz, the height of which, DF, is equal to half of its diameter AD. Bisect AD in C, and join CK, CG, and draw CE parallel to AB or DF. This line CE will be the axis of the prism. Grind and polish the section ABFD, and cut off the prisms AKCBLE and DGCFHE, setting aside the intermediate similar prism KGCLHE. The faces ACEB, DCEF are square and equal, so that if we cement these faces together, making the line AB coincide with FE, AC will coincide with FD, CE with DC, and EB with CE. If we wish each prism to have an angle of 60°, we may take either GDFH or GCEH for the refracting face of it; we shall suppose the former. In this case we must grind and polish a face on the other prism ABL, which is accurately parallel to the face GDFH, and the compound prism will be completed. If 60° is too great, we must grind down the face GDFH till it has the desired inclination to DF, and grind and polish a face parallel to it on the other prism. The external faces, in short, to be made upon each prism must be equally inclined to the cemented planes DCEF, ABEC, and have their common section DF parallel to the axis CE of the prism. In place of cutting off the prism AKCBLE, we may cut off only the prism GCDHEF, leaving the intermediate one GKCHLE attached to AKCBLE, and proceed as before. The object of this is to leave enough of solid quartz at KL to give a face of the same breadth as GDFH. If the prisms required are small compared with the quartz-crystal, we may obtain, by the first method, six prisms out of the crystal, or three pair of compound ones. On the other hand, if the required prism is large compared with the crystal of quartz, it may require one-half of the crystal to make one prism, and the other half the other. Nay, it may be necessary to cut each individual prism out of separate crystals, the method of doing which is very obvious from the preceding description.

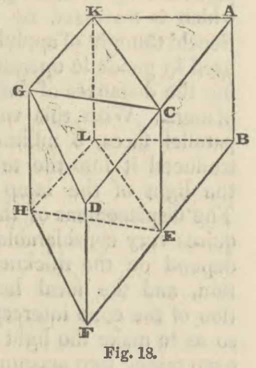

Fig. 18.

Double-Image Micrometers.

When the prism is completed, it is evident that a ray of light incident perpendicularly on the face GHFD will be perpendicular to the axis of the prism CE, and therefore the extraordinary ray will suffer the greatest deviation, viz. 17′: and the same is true of the other prism. But when the ray passes through both, it is found to have a deviation of 34′, which is produced in the following manner: Let AB be a line viewed through one of the prisms, with its refracting angle turned upwards; two images of it will be seen, viz., the extraordinary image at E, and the ordinary one at O. If we now interpose the other prism with its refracting angle downwards, both these images E, O will be refracted downwards. But owing to the transverse cutting of the prisms, the extraordinary image E, which was most raised, now suffers ordinary refraction, and is least depressed, so that in place of being refracted back to AB, it comes only to E′O′. On the other hand, the ordinary image O, which suffered the least refraction, is now extraordinarily refracted, and, in place of reaching AB, is depressed to O′E′; and since the double refraction of each prism, as well as the angles of the prism, are equal, the angular distance of the images E′O′, O′E′ formed by the combined prisms will be double of the distance EO, or 34′.

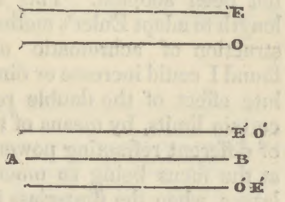

Fig. 19.

The same rule may be followed in cutting the prism out of the limpid and homogeneous topazes of New Holland, the principle axis of which coincides with the axis of the prism. When the crystals are amorphous, the cleavage planes will be a sufficient guide, as the above axis is always perpendicular to them. Such prisms are incomparably superior, as we have practically experienced, to those made of rock-crystal.

When a very large angle is required for any particular purposes, artificial crystals, such as carbonate of potash, &c., may be advantageously employed, the crystals being ground with oil, or any fluid in which they are not soluble. By cementing plates of parallel glass on their outer surfaces they will be as permanent as rock-crystal.

Dr Pearson fitted up with one of Rochon's micrometers an achromatic telescope 33 inches in focal length, and having a magnifying power of 35½. He applied it to two separate compound prisms, one of which had a constant angle of 32′, and the other an angle only of 5′, the vernier in the former case indicating seconds, and in the latter tenths of seconds. A drawing is given of the tube, with

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[1] In his first experiments Rochon corrected the dispersion of the rock-crystal prism by a similar prism placed in front of it, and having its exterior face perpendicular to the axis of the crystal. This prism, having no effect in doubling the image, gave him a complete correction of the dispersion for the ordinary image.

[2] *Phil. Trans.* 1820, p. 126.

Double-Image Micrometers.

the prisms and scales in figs. 20, 21, as given by Dr Pearson. The tube is graduated from the solar focus into two scales, one being placed on each side of the slit or opening cut along the middle of the tubes, to allow the sliding-piece, shown separately in fig. 21, to move from the object-glass to the solar focus. This sliding-piece holds the prism, the larger prism of 32′ being shown as placed with its sliding-piece in the tube, and the smaller prism of 5′ being shown in the separate sliding-piece (fig 20). The two verniers of the scales are seen on each side of the two screws with milled heads, which pass through the slit, and serve to move the sliding-piece to or from the object-glass when they are not too much tightened.

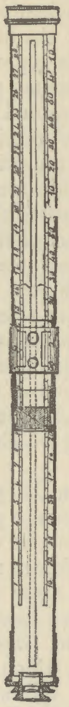

Fig. 20.

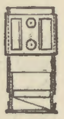

Fig. 21.

In his original memoir on the subject, published in the *Journal de Physique* for 1801,[1] M. Rochon makes the following observations:—"I ought not to omit that in this new construction there are difficulties of execution not easy to surmount, which may have been one reason why these instruments, so useful to navigators, and in certain very nice astronomical observations, have not been adopted. This induced me at length to adopt Euler's method. In the construction of achromatic object-glasses I found I could increase or diminish the absolute effect of the double refraction within certain limits, by means of the interval between the glasses of different refracting powers; the separation of the images at the focus being so much the greater, as the interval is larger, when the flint-glass is the first of the object-glasses, and less when it is the second. Conformably to these new principles, I have had two telescopes with a doubly-refracting medium constructed under my own inspection, which General Gantheaume will employ for determining the position of his ships, and to find whether he be approaching any he may meet with at sea."[2]

Rochon's second micrometer.

In 1812 M. Rochon constructed his doubly-refracting micrometer in another form, from which he anticipated great advantages. He made a parallelopiped of rock-crystal, consisting of two prisms whose refracting angles were each about 30°, so that the angle which they gave was less than 30′, and the two images of the sun of course overlapped each other. The prisms being firmly united by mastic, he ground the parallelopiped into a convex lens, so that when combined with a concave one of flint-glass, it formed an achromatic object-glass with a focal length of about 3 decimetres, or nearly 12 inches. This object-glass separated the centres of the images of the sun about 28 minutes. "He then adapted to this object-glass a common micrometer, which measured angles of 10 minutes, and he had thus three decimetres and 10 minutes to complete the measure of the diameters of the sun or moon."

Arago's doubly-refracting micrometer.

M. Arago, as he himself informs us, employed Rochon's micrometer in taking more than 3000 of the diameters of the planets. He found, however, that he could not make both the images equal in diameter at the same time, and that with high powers this defect was intolerable. When the prism, too, was near the eye-glass, for the determination of the zero of the scale or for the measure of very small angles, the smallest imperfections in the crystal, or in the state of its surfaces, were considerably magnified. In order to remedy this inconvenience he placed the prism without the telescope, between the eye-glass and the eye, at the place where the darkening glasses for observing the sun are fixed. The contact of the two images was then obtained by Sir David Brewster's method of varying the magnifying power of the telescope, as shown in fig. 5, where the two lenses of the eye-piece next the eye are moved to and from the other two lenses. M. Arago, however, having found that this change in the eye-piece was an inconvenience, kept the magnifying power constant, and employed a large number of doubly-refracting prisms in which the angles succeeded one another by variations of 30 and even 15 seconds. By this means he selected the prism which brought the two images nearest into contact. He then took the next, in which the images overlapped, and took the mean of their angles, which he divided by the magnifying power of his telescope. "With prisms," he remarks, "succeeding one another by 15 seconds, and with a magnifying power of 200, each measure will differ from that of the preceding prism by $\frac{15''}{200}$, or $\frac{7}{100}$ths of a second. The uncertainty, therefore, of the mean will be scarcely $\frac{4}{100}$ths, a quantity which may be safely neglected. Previous to the construction of this micrometer, which he describes in the *Comptes Rendus* for 1847,[1] M. Arago seems to have used another form of the instrument, in which, as Dr Pearson informs us,[2] the constant angle was increased by placing the prism in an oblique direction as regards the line of vision; and in which "he determined the respective values of the angles thus increased by means of concentric circles placed vertically at a measured distance from the eye when looking through the prism; for as he knew the diameters of each circle, he could generally find out one of the number which would come into exact contact with its image, and thus give the value of the constant angle."

Micrometers of Porro and Secchi.

A micrometer with double images was executed and used by M. Porro of Paris in 1842, and more recently by M. Secchi, astronomer to the Collegio Romano. M. Porro gives to his micrometer the name of *The Parallel Independent Micrometer*. It consists of a parallel plate of glass placed within the telescope, so that part of the rays from any object pass through it, and another part past it. By a greater or less inclination of the plate, two images of the object may be either superposed or be made to touch alternatively by one side or by another. The change of inclination of the plate gives the measure of the discs or angles required. In order to correct the elongation of the focus of the half pencil which traverses the glass, it is compensated by a fixed glass of the same thickness as that which is traversed by the other half of the pencil. M. Secchi thought of applying this micrometer, which had been used in geodetic operations, to large telescopes for measuring the distances of double stars and the diameters of the planets. With this view he took a plate of glass with parallel faces, 3 millimetres thick and 12 wide, and introduced it into the telescope by the hole through which the light of the lamp passes for illuminating the wires. The displacement of the images, which are very small, requires very considerable inclinations of the plate, and they depend on the thickness of the plate, its index of refraction, and the focal length of the telescope. The position of the cone intercepted by the plate may be regulated so as to make the light of the two images perfectly equal, even taking into account the reflection produced by the surfaces of the plate. M. Secchi applied this micrometer to the telescope of 7 feet of Cauchoix, and one of 14 feet by Merz, and found it to give good results. He remarks, however, that for telescopes of short focus, and perhaps for large ones with high magnifying powers, the displacing plate of parallel glass should be slightly concave, in order to lengthen a little the focus which the displacement shortens. M. Porro disapproves of making the plate concave. He fixes the micrometer on a separate stand, so as to be independent of the position of the telescope, though within it.[1] The displacement d of the image is found by the following formulæ :—

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[1] Translated in Nicholson's Journal, 8vo., vol. iv., p. 110-120.

[2] *Ibid.*, p. 117.

[1] Tom. xxiv., p. 400.

[2] *Introduction to Practical Astronomy*, vol. ii., p. 206-212.

$$d=t\,\frac{\sin \mathrm{I}-\mathrm{R}}{\cos \mathrm{R}},$$

$$\text{and } \sin \mathrm{R}=m \sin \mathrm{I};$$

t being the thickness of the glass, m its index of refraction, I the inclination of the plate or the angle of incidence, and R the angle of refraction. The value of I is given by the instrument to the 100th part of a degree.[2]

Pearson's ocular crystal micrometer.

Dr Pearson has proposed an *ocular crystal micrometer*, and has given a drawing and description of the instrument.[3] It is nothing more than M. Arago's ocular crystal prism, in which the constant angle is varied by Sir David Brewster's variable eye-piece already described. On the same principle, the angle of the prism may be varied by a convex or concave lens moving between the object-glass and its principal focus; but what would be still better, by pulling out or pushing in the eye-piece of a Gregorian or Cassegrainian telescope.

Mr G. Dollond's spherical crystal micrometer.

In 1821 Mr George Dollond communicated to the Royal Society an account of his spherical crystal micrometer, a very ingenious instrument, though, we should think, one difficult to execute; and at the same time, even when well executed, liable to error. Mr Dollond's improvement consists in making a sphere or lens from a piece of rock-crystal, and adapting it to a telescope in place of the usual eye-glass, as shown in fig. 22, where a is the sphere or lens, formed of rock-crystal, and placed in *half holes*, from which is extended the axis bb, with an attached index, the face of which is shown in fig. 23. This index registers the motion of the sphere on the graduated circle. The sphere a is so placed in the half holes that when its natural axis (axis of double refraction, we presume) is parallel to the axis of the telescope, it gives only one image of the object. In a direction perpendicular to that axis it must be so placed that when it is moved the separation of the images may be parallel to that motion. The method of acquiring this adjustment is by turning the sphere a in the half holes parallel to its own axis. A second lens d is introduced between the sphere and the primary image given by the object-glass, and its distance from the sphere should be in proportion to the magnifying power required. The magnifying powers engraven in fig. 23 are suited to an object-glass of 44 inches focal length. The following are the advantages of this construction as stated by its inventor :— 1. It is only necessary to select a piece of perfect crystal, and, without any knowledge of the angle that will give the greatest double refraction, to form the sphere of a proper diameter for the focal length required. 2. The angle may be taken on each side of *zero* without reversing the eye-tube; and intermediate angles may be taken between zero and the greatest separation of the images without exchanging any part of the eye-tube, it being only required to move the axis in which the sphere is placed. 3. It possesses the property of a common eye-tube and lens; for, when the axis of the crystal is parallel to that of the object-glass, only one image will be formed, and that as distinctly as with any lens that does not refract doubly.[1]

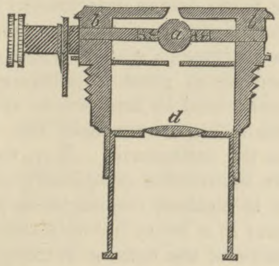

Fig. 22.

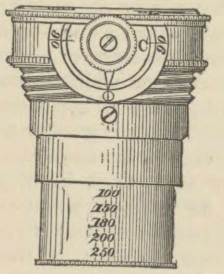

Fig. 23.

Dr Pearson had one of these instruments constructed by Mr Dollond, and applied to an achromatic object-glass 43·6 inches in focal length. He has shown that the scale is not one of equal parts, and has pointed out a method of determining the constant angle of the crystal.

Knowing from experience the imperfect structure of rock-crystal, especially in directions approaching to the axis, we dreaded that a spherical eye-glass of this material would not give perfect vision. Dr Pearson confirms this opinion by actual observation. He attempted to measure the diameter of Mars when about 9″, "but its limits were so imperfectly defined that no satisfactory observation could be made."[2] We would therefore strongly recommend the substitution of limpid topaz from New Holland in place of the rock-crystal.

CHAP. VI.—DESCRIPTION OF POSITION-MICROMETERS.

Position-micrometers.

A position-micrometer is an instrument for measuring angles when a plane passing through the two lines which contain these angles is perpendicular to the axis of vision. Sir W. Herschel first proposed such an instrument for the purpose of verifying a conjecture, that the smaller of the two stars which compose a double star revolves round the larger one. Hence it became necessary to observe if a line joining the centres of any two stars always formed the same angle with the direction of its daily motion. After constructing the instrument which we are about to describe, and making a long series of observations, he verified his conjecture by the important discovery that the double stars formed binary systems, in which the one revolved round the other. The position-micrometer used by Sir William Herschel in his earliest observations, viz., those made in 1779-1783, was made by Nairne, and was constructed as shown in fig. 24, which represents it when inclosed in a turned case of wood, and ready to be screwed into the eye-piece of the telescope. "A is a little box which holds the eye-glass. B is the piece which covers the inside work, and the box A screwed into it. C is the body of the micrometer, containing the brass-work, showing the index-plate a projecting at one side, where the case is cut away to receive it. D is a piece having a screw b at the bottom, by means of which the micrometer is fastened to the telescope. To the piece C is given a circular motion, in the manner the horizontal motion is generally given to Gregorian reflectors, by the lower part going through the piece D, where it is held by the screw E, which keeps the two pieces C and D together, but

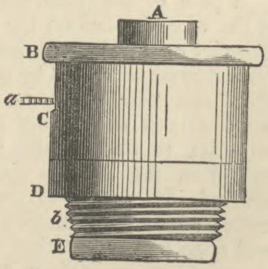

Fig. 24.

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[1] See Porro in the *Comptes Rendus*, tom. xli., p. 1058, Dec. 10, 1855; and M. Secchi, tom. xli., p. 906, Nov. 19, 1855.

[2] *Id. Id.*, 1854, vol. xxxix., p. 245.

[3] *Introduction to Practical Astronomy*, vol. ii., p. 219.

[1] See *Phil. Trans.*, 1821, p. 101-104.

[2] *Introduction to Practical Astronomy*, vol. ii., p. 233.

Position-Micrometers.

Sir W. Herschel's position-micrometer.

leaves them at liberty to turn on each other. Fig. 25 is a section of the case containing the brass-work, where may be observed the piece B hollowed out to receive the box A, which consists of two parts inclosing the eye-lens. This figure shows how the piece C passes through D, and is held by the ring E. The brass-work, consisting of a hollow cylinder, a wheel and pinion, and index-plate, is there represented in its place. F is the body of the brass-work, being a hollow cylinder with a broad rim C at its upper end; this rim is partly turned away to make a bed for the wheel *d*. The pinion *e* turns the wheel *d*, and carries the index-plate *a*. One of its pivots moves in the arm *f*, screwed on the upper part of *c*, which arm serves also to confine the wheel *d* to its place on *c*. The other pivot is held by the arm *g* fastened to F.

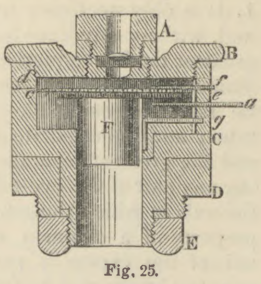

Fig. 25.

A section of the brass-work is shown in fig. 26, where the wheel *d* which is in the form of a ring inlaid on the upper part of F or C, and held by two small arms *f*, *h*, screwed down to *e* with the screws *i*, *i*.

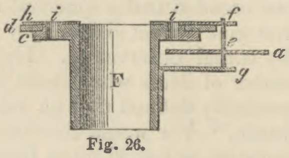

Fig. 26.

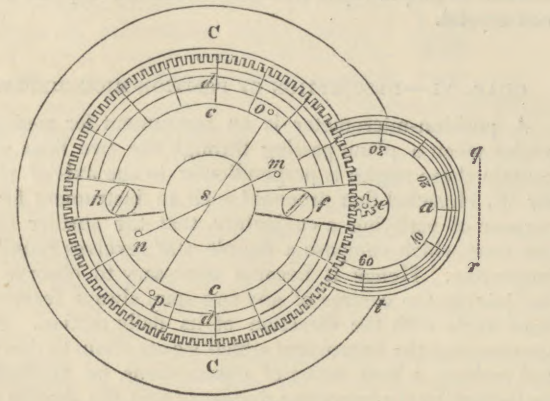

Fig. 27.

A plan of the brass-work is shown in fig. 27, where *dd* is the wheel placed on the bed or socket of the rim of the cylinder *cc*, and is held down by the two pieces *f*, *h*, which are screwed on *cc*. The piece *f* projects over the centre of the index-plate to receive the upper pivot of the pinion, *mn* the fixed wire being fastened to *cc*, and the movable wire *op*, to the annular wheel *dd*. The index-plate *a*, milled on the edge, is divided into sixty parts, each subdivided into two. When the finger is drawn over the milled edge of the index-plate from *q* to *r*, the angle *mso* will open by the rotation of the movable wire *op*, and if drawn from *r* towards *q*, it will shut again. The case CC must have a sharp corner *t*, which serves as an index to point out the divisions on the index-plate.[1] In using this micrometer the movable wire *op* is placed in the direction of the apparent motion of the principal star, and the other wire *mn* made to form such an angle with it that both the stars arrive at this wire at the same time. The inclinations of the wire measured on an index-plate gives the *angle* of position, or that which the line joining the centre of the stars forms with the direction of their daily motion.

We do not know the value of the divisions in the instrument used by Sir William Herschel; but in the position-micrometer of the five-feet equatorial used by Sir John Herschel and Sir James South, in their observations on double stars, the position circle was large enough to show distinctly minutes of a degree by means of its vernier. Since the time of Troughton an important improvement has been made in this micrometer, by separating the position motion from the linear motion. This is done by causing a foot or two of the end of the telescope which carries the wire-micrometer to revolve on the rest of the tube, thus securing a larger circle for the readings, and a firmer motion than could be obtained when all the movements were included in the micrometer itself.

Position-Micrometers.

Troughton's improvement.

The position-micrometer which we have now described has been improved by Sir David Brewster; and the following account of these improvements, which is not susceptible of abridgment, is given in his own words:—

Improved position-micrometer.

In the position-micrometer invented by Sir William Herschel, "the two wires *mn*, *op* always cross each other at the centre of the field *s*, and consequently their angular separation is produced uniformly by the motion of the pinion. This very circumstance, however, though it renders it easy for the observer to read off the angle from the scale, is one of the greatest imperfections of the instrument. The observations must obviously be all made on one side of the centre of the field, as appears from fig. 27; and the use of the instrument is limited to those cases in which the distance of the stars is less than the radius of the field. The greatest disadvantage of the instrument, however, is the shortness of that radius; for the error of observation must always diminish as the length of this radius increases. This disadvantage does not exist in measuring the angle of position of two stars; for the distance remains the same whatever be the radius of the field; but in determining the angle which a line joining two stars forms with a line joining other two stars, or those which compose a double star (an observation which it may often be of great importance to make), and all other angles contained by lines whose apparent length is greater than the radius of the field, this imperfection is inseparable from the instrument. Nay, there are some cases in which the instrument completely fails; as, for instance, when we wish to measure the angles formed by two lines which do not meet in a focus, but only tend to a remote vertex. If the distance of the nearest extremities of these lines is greater than the chord of the angle which they formed measured upon the radius of the field, then it is impossible to measure that angle, for the wires cannot be brought to coincide with the lines by which it is contained. Nay, when the chord of the angle does exceed the distance between the nearest extremities, the portion of the wires which can be brought into coincidence with the lines is so small as to lead to very serious errors in the result.

The new position-micrometer which we propose to substitute for this instrument is free from the defects just noticed, and is founded on a beautiful property of the circle. If any two chords, AB, CD (fig. 28), intersect each other in the point O within the circle, the angle which they form at O will be equal to half the sum of the arches AC, BD; but if these chords do not intersect each other within the circle, but tend to any point O without the circle, where they would intersect each other if continued, as in fig. 30, then the angle which they form is equal to half the difference of the arches AC, BD; that is, calling ϕ the angle required, we have, in the first case, as shown in fig. 28,

$$\phi=\frac{\mathrm{AC}+\mathrm{BD}}{2};$$ and in the second case, as shown in fig. 30,

$$\phi=\frac{\mathrm{AC}-\mathrm{BD}}{2}.$$ Hence, if the two wires AB, CD be placed

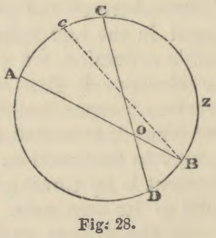

Fig. 28.

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[1] *Phil. Trans.*, 1781, p. 500.

Position-Micrometers.

in the focus of the first eye-glass of a telescope, the movable one AB may be made to form every possible angle with the fixed one CD, and that angle may be readily found from the arches AB, CD.

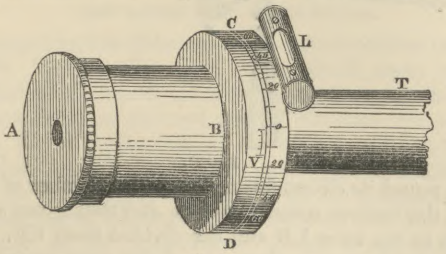

Fig. 29.

The mechanism for measuring these arches is shown in fig. 29, where the graduated circular head CD may be divided only into 180°, in order to save the trouble of halving the sum or the difference of the arches AC, BD; but as it would still be necessary to measure *two* arches before the angle could be ascertained, we have adopted another method, remarkable for its simplicity, and giving no more trouble than if the wires always intersected each other in the centre of the field.

Let AB, for example (fig. 30), be the fixed wire, and CD the movable one, and let it be required to find at one observation the angle AOC or ϕ. Set the index of the vernier to *zero*, when D coincides with B; and as C will be at *c* when D is at B, the arch *c*A will be a constant quantity, which we shall call *b*. Making AC$=m$, and BD$=n$, we have $\phi=\frac{m+n}{2}$. But since the extremity C will move over the space C*c* while D describes the space DB, these arches must be equal, consequently $b=m-n$; hence, adding $2n$ to each side of the equation, we obtain $b+2n=m+n$, or $\frac{1}{2}b+n=\frac{m+n}{2}$, consequently $\phi=\frac{1}{2}b+n$. Hence the angle AOC is equal to half the arch A*c* added to the arch DB; or, since A*c* is invariable, the half of it is a constant quantity, and the angle required is equal to the sum of this constant quantity and the arch DB.

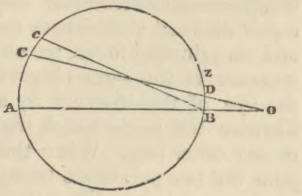

Fig. 30.

When the wires do not intersect each other, as in fig. 30, we have $\phi=\frac{m-n}{2}$, and $b=m+n$; hence, subtracting $2n$ from each side of the equation, we have $b-2n=m-n$, and, dividing by 2, we have $\frac{1}{2}b-n=\frac{m-n}{2}$, consequently $\phi=\frac{1}{2}b-n$. That is, the angle AOC is equal to the difference between half the arch A*c* and the arch DB, or to a constant quantity diminished by the arch DB.

In finding the angle AOC, therefore, we have merely to observe the place of the index when the wires are in their proper position; and as the scale commences at B, or where D and B coincide, and is numbered both ways from B, the degree pointed out on the circular head CD, when increased or diminished by the constant quantity, will give the angle of the wires which is sought. The semicircle on each side of a diameter drawn through B is divided into 180°, the 180th degree being at the opposite end of that diameter.

We may simplify still further the method of reading off the angle AOC, so as to save the trouble even of recollecting the constant quantity, and of adding it to, or subtracting it from, the arch pointed out by the index of the vernier. This advantage is obtained by making the index of the vernier point to the constant quantity upon the part of the scale below B (fig. 28) when the points D, B coincide, or when the wire CD is in the dotted position *c*B; for it is obvious that if *z* marks the zero of the scale, and B*z* is equal to the constant quantity, the arch D*z*, which is pointed out by the index of the vernier, will be equal to $\frac{1}{2}b+n$, or the angle AOC. In like manner, in fig. 30, where the wires do not cross each other within the field, and where B*z* is the constant quantity, the arch D*z* marked out by the index of the vernier is obviously equal to $\frac{1}{2}b-n$, or the angle AOC, which the wires tend to form at O. By means of this adjustment, therefore, we are able to read off the angle AOC with the same facility as if the wires intersected each other in the centre of the field, when the arches are accurate measures of the angles at the centre.

Position-Micrometers.

The end of the eye-tube is represented in fig. 29, where the circular head CD is divided into 360°, and subdivided by the vernier V. L is the level, and AB the part of the eye-piece which contains the diaphragm, with the fixed and movable wires. The head CD and the level L are firmly fixed to the eye-tube T; and from the head CD there rises an annular shoulder, concentric with the tube and containing the diaphragm, across which the fixed wire is stretched. This diaphragm, which is represented in fig. 31, with the wire extended across, projects through the circle of brass EF. All these parts remain immovable, while the outer tube AB, and the other half EF, of the circular head which contains the vernier V, have a rotatory motion upon the shoulder, which rises from CD. The tube AB is merely an outer case, to protect a little tube within it, which contains the eye-glass and the movable diaphragm, with its wire extended across it. The inclosed tube is screwed into the ring EF, and the outer tube is also screwed upon the same ring, so that by moving AB a motion of rotation is communicated to the vernier V, and to the diaphragm and wire belonging to the inner tube, while the rest of the eye-piece, containing the other diaphragm with its wire, remains stationary. By these means the movable wire is made to form every possible angle with the fixed wire, and the angle is determined by the method which we have already explained. The fixed wire is placed a good deal out of the centre of the diaphragm to which it belongs; and the diaphragm itself is placed in a cell, in which it can be turned round so as to adjust the wire to a horizontal line when the level is set. The movable wire is likewise placed at a distance from the centre of its diaphragm, as shown in fig. 32; but by means of screws which pass through the inner tube into the edge of this diaphragm, it can be moved in a plane at right angles to the axis of the eye-piece, so that the movable wire may be placed either in the centre of the field or at different distances from it.

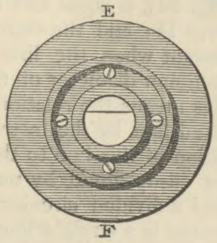

Fig. 31.

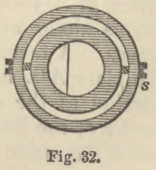

Fig. 32.

Double-image micrometer a position-micrometer.

The double-image micrometer affords a convenient method of measuring angles of position; and we believe this application of it was first made by Sir David Brewster.

In every instrument in which a double image of an object is formed by means of two semi-lenses with their centres at a distance, the one image appears to have a rotatory motion round the other when the telescope is turned about its axis. Thus in fig. 33, if A, B be images of two objects formed by the upper semi-lens when the common

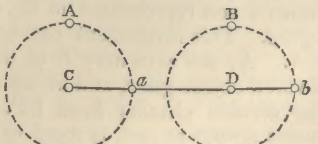

Fig. 33.

Position Micrometers.

diameter of the semi-lenses is perpendicular to the horizon, and C, D the images of the same objects formed by the lower semi-lens; then, by turning the telescope about its axis, or the semi-lenses round in their tube, the image A will appear to move round C in the circle A*a*E, and the image B round D in the circle B*b*F, or in the opposite direction if the telescope or the semi-lenses are turned the other way. When the distance AC is equal to CD, as in fig. 34, the image A will pass over the image D; or if the telescope is turned in the opposite direction, the image B will pass over the image C. In like manner, when AC is greater or less than CD, the images will move as we have represented them in figs. 33 and 35. In all these cases the four images may be brought into one straight line; and when this takes place the line which passes through all the images will uniformly form the same angle with the horizon as the common diameter of the semi-lenses. It is very easy to ascertain with the utmost accuracy when the images form one straight line; but particularly in the case where AC (fig. 34), is equal to CD, for the image of A will then pass over D; and the coincidence of the images will mark the instant when the line which joins them is parallel to the common diameter of the lenses. Hence, as we obtain by this means the relation of the line joining the images to a fixed line in the instrument, the relation of this line to the horizon may be easily found by means of a level and a divided circular head. If the image is a straight line (fig. 35), then the coincidence of the two images, so as to form one straight line, will indicate the parallelism of that line to the diameter of the semi-lenses.

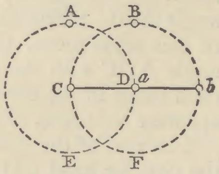

Fig. 34.

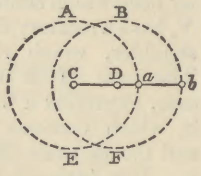

Fig. 35.

In constructing a micrometer of this kind solely for the purpose of measuring angles when the eye is not at their vertex, either the object-glass or the third eye-glass might be made the divided lens. If the object-glass is divided, it should be so constructed that it may have a rotatory motion in its cell, by applying the hand to a milled circumference AB (fig. 36). Connected with the tube TT of the telescope is a circular ring of brass CD divided into 360°; and the divisions upon this scale are pointed out by the index of a vernier *v*, which moves along with the semi-lenses. A level L is fixed to the plate AB, having its axis parallel to the common diameter of the lenses, and being adjusted to a horizontal line when the index points to the zero of the scale. In using the instrument, therefore, the observer turns round the semi-lenses by means of the projecting milled circumference AB, till the coincidence of the two images is distinctly perceived. The index of the vernier will then point out upon the graduated head the inclination of the line which is required.

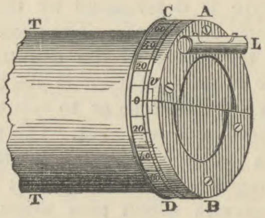

Fig. 36.

When the telescope is long, this form of the instrument, though extremely simple, is not very convenient. The construction represented in fig. 37 is in general to be preferred. This instrument consists of three tubes BL, LC, CA. At the extremity B of the first tube is placed the divided object-glass, and at the other extremity L is fixed the divided circular head EF. The tube CL, which remains always at rest, is fixed to the stand HI by means of the clasp and screw at H. The tube AC, which contains an eye-piece, moves within both the tubes CL and LB. The tube BL extends towards C, the tube CL being within it, and round its circumference are cut a number of teeth, in which the endless screw G works, and thus gives a rotatory motion to the tube LB and the divided head EF. By this means the common diameter of the semi-lenses at B is made to form every possible angle with a horizontal line, which is indicated by a level above L, having its axis parallel to the common diameter of the semi-lenses. The index of the vernier *v*, fixed to the stationary tube CL, points out on the graduated head the angle required. When the instrument is constructed so that the semi-lenses are in the eye-piece, the graduated head must be placed in the eye-tube.

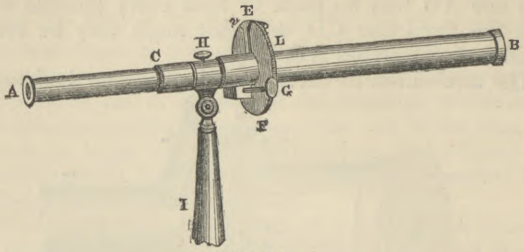

Fig. 37.

If the principle of this micrometer is applied to the double-image micrometer described in chap. iv., in which a pair of fixed semi-lenses moves between the object-glass and its principal focus, we obtain an instrument which will measure at the same observation the angle subtended at the eye of the observer by a line joining two points, and likewise the angle which that line forms with the horizon or any other line. When the two images of the line which joins the two points are brought into contact by the motion of the semi-lenses along the axis of the tube, these images must necessarily be in the same straight line, so that the relation of that line to the horizon, or to any other given line, and the contact of the two images of it which determines its angular magnitude, are obtained simultaneously without any additional observation or adjustment.

Dr Pearson has given some very useful details respecting the use of double-image micrometers in measuring angles of position.[1]

Linear disc micrometer.

When the brightness of the two stars which compose a double star is considerable, their discs may be drawn out into lines of light either by cylindrical refraction or reflection, and the coincidence of these lines will furnish the means of determining the angle of position.

Lucid disc position micrometer.

A position-micrometer upon a new principle has been proposed by Sir David Brewster. He expands the images of the two stars into luminous discs till they overlap each other. The southern limb of the lower disc is then made to move along the fixed wire of the position-micrometer. A line joining the two points where the circumferences of the discs intersect each other is obviously perpendicular to a line joining the centres of the stars, and will therefore form an angle with the fixed wire equal to the complement of the angle of position required. If we therefore make the movable wire pass through the two points where the luminous discs intersect each other, the micrometer scale will give the complement of the angle of position.[2]

Photographic position micrometer.

By the photographic process, already referred to (chap. i.), dark lines may be formed on transparent collodion or albumen at fixed angles, succeeding one another, like Arago's prisms, by angles differing 30″, 15″, or even 5″. These lines may converge to points within or without the field, or even to points at great distances; and in the latter case their inclination may be nicely determined in the large or unreduced copy by a divided circle furnished with a vernier read off by microscopes. A movable photographic line on a plate of collodion upon glass may have a motion close to the plate containing the other lines, and the foci of both made equally distinct by optical means.

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[1] *Introduction to Practical Astronomy*, vol. ii., p. 255.

[2] *Treatise on New Philosophical Instruments*, p. 45.

CHAP. VII.—DESCRIPTION OF THE LAMP-MICROMETER AND THE LUCID-DISC MICROMETER.

Lamp micrometer.

In measuring the distances and angle of position of double stars Sir William Herschel encountered many practical difficulties which interfered with the accuracy of his results. The uncertainty of the real zero of his scale, the inflexion of light, the imperfections of the screws and divided bars and pinions, and the difficulty of obtaining fibres sufficiently minute for his purpose, but, above all, the disappearance of small stars by the illumination of the wire, led this eminent astronomer to the contrivance of his *lamp-micrometer*, which, while it is exempt from these sources of error, has also the advantage of a large scale.

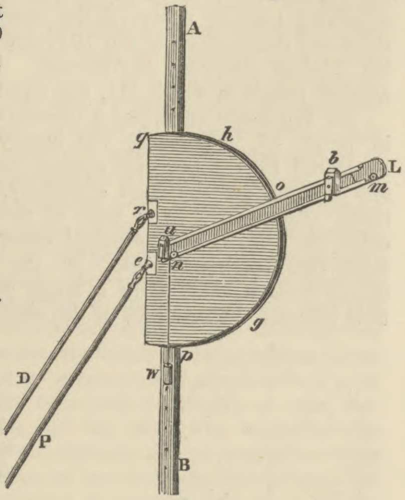

Fig. 38.

The lamp-micrometer is represented in fig. 38, where AB is the upright part of the stand, 9 feet high, upon which a wooden semicircle *qhogp*, 14 inches radius, may be fixed at different heights by a peg *p* put into holes in the stand. An arm L, 30 inches long, moves round a pivot in the centre of the board by means of the handle P, which works a string *eqho* fastened to a hook at the back of L. The arm L is kept at any inclination to the horizon by the weight of the handle P, which is 10 feet long. A small slider *b*, about three inches long, moves along the front of L towards and from the centre at *u*, by means of the handle *r*D, which operates by a string passing over the pulley *m*, and returning by *n* to a barrel at *r*, while a second string *bnw*, with a weight *w*, causes the slider *b* to return to the centre. The end of the arm L is shown on a large scale in fig. 39.

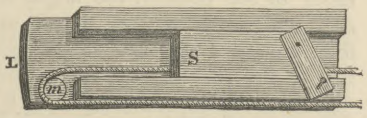

Fig. 39.

Two lamps *a*, *b* (figs. 40 and 41), $1\frac{1}{2}$ inch high and $1\frac{3}{4}$ inch deep, have sliding doors with small apertures made with a fine needle opposite the flame of a single cotton-thread wick, so that when the sliders are shut down, nothing is seen but two fine lucid points like stars of the third or fourth magnitude. The lamp *a* is placed at the centre *u*, so that its lucid point may occupy that centre, while *b* is hung on the slider S, so that its lucid point may be in a line with the lucid point of *a* when the arm L has a horizontal position.

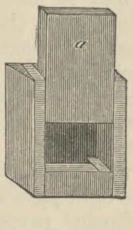

Fig. 40.

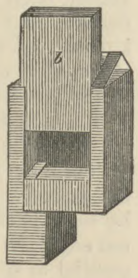

Fig. 41.

A person, therefore, at a distance of 10 feet may govern the two lucid points so as to bring them into any required position by the handle P; and by the handle D he may place them at any distance, from $\frac{6}{10}$ths of an inch to 25 inches.

In using this micrometer Sir W. Herschel placed it 10 feet from his left eye, while with his right he viewed a double star through his Newtonian reflector. By means of his left eye the double star is seen projected upon the micrometer, and he then placed his two lucid points at such a distance that they were exactly covered by the stars. The distance of the lucid points was the tangent of the magnified angles subtended by the stars to a radius of 10 feet. This angle, therefore, being divided by the magnifying power of the telescope, gives the real angular distance of the centres of a double star. With a power of 460 the scale was a quarter of an inch for every second. Sir W. Herschel, in measuring the apparent diameter of *α Lyræ* with this instrument, used a magnifying power of 6450. The magnified angle was 38′ 10″, so that the real angle was $\frac{38' \, 10''}{6450} = 0''\!\cdot\!355$, giving on this occasion a scale of no less than $8\frac{1}{2}$ inches to a second.[1]

Lucid-disc micrometer.

In using high magnifying powers Sir W. Herschel employed another apparatus called the lucid-disc micrometer. A lucid disc made of oiled paper, or any other semi-transparent substance, was placed in the front slider of a lantern, and illuminated by a flame behind it. The lantern was then removed to a distance till the diameter of the disc appeared equal to that of a planet seen in the telescope, so that the angular diameter of the planet became known by dividing the angle subtended by the disc by the magnifying power of the telescope. The result was affected by the colour of the disc and the degree of illumination. The measure was always too small when the illumination was strong, and too great when a black disc was placed on an illuminated ground. Hence Sir William Herschel took a mean of the two as the true measure.

M. Schroeter of Lilienthal, in measuring the diameter of Vesta, Juno, Pallas, and Ceres, used a lucid-disc micrometer, which we presume was not much different from Sir W. Herschel's.

Dr Pearson constructed and used an analogous instrument, in which the left eye looked into a tube containing a system of lines upon a disc of glass, or a spider's line micrometer, so that the object seen with the right eye was projected against these divisions, and its angular diameter ascertained.[2]

CHAP. VIII.—DESCRIPTION OF FIXED MICROMETERS WITH AN INVARIABLE SCALE.

Huygens's micrometer.

The earliest fixed micrometer of which we have a distinct account is that of Huygens, who placed a circular diaphragm in the focus of the eye-glass of his telescope, and found its angular value to be seventeen and a quarter minutes by the time which a star took to pass across it. He then formed two or three long brass plates of different breadths so as to form wedges of different angles. In measuring the diameter of a planet with one of these, he made one of them slide through two slits in the opposite sides of the tube, so that the plane of the brass wedges touched the plane of the circular diaphragm; and having observed in what part of the wedge its breadth just covered the whole planet, he took this breadth in a pair of compasses, and having found what part it was of the whole aperture, he divided seventeen and a quarter minutes by this part, and obtained the diameter required. Sir Isaac Newton has stated that the measures thus taken are always in excess. Had Huygens used long wedge-shaped slips or openings, he would by the same process have obtained measures which erred in defect, and the mean be-

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[1] *Phil. Trans.*, vol. lxxii., p. 102.

[2] *Introduction to Practical Astronomy*, vol. ii., p. 245.

Fixed Micrometers.

tween these two measures would have given the true diameter of the planet.

Cassini's reticle. The reticle (*reticulum*) or fixed micrometer, composed of wires, was invented and used by Cassini. It is shown in the annexed figure, where *ab*, *cd*, *ef*, *gh*, are four hairs or wires intersecting each other at right angles at *i*, in the focus of the eye-glass, *ab*, *cd* being inclined 45° to *ef* and *gh*. In order to find with this apparatus the differences of the right ascension and declination of two stars, direct the telescope so that the first or *preceding* star may appear upon the wire *ab*, and turn round the tube till that star moves along *ab*. The time when this star reaches *i* is carefully noted, and also the time when the *following* star reaches the wire *cd*. The interval between these times, converted into degrees, is the difference of right ascension required. To find the difference of their declinations, mark the time of the second or *following* star's arrival at the points *k* and *l* of the oblique wires *ef*, *gh*. The half of the interval between these times is the time in which the star describes the space *lm* or *mk*, which, converted into degrees, is the angular distance *lm*, which, multiplied by the cosine of the declination of the known or preceding star, gives an approximate difference, which, when applied to the declination of the known star, gives the approximate declination of the unknown or following star. If we now multiply the angular value of *lm* by the cosine of this approximate declination, we shall have the correct difference of declination, which, applied to the declination of the known star, will give the true declination of the unknown star.

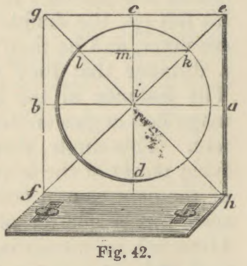

Fig. 42.

Bradley's reticle. In using the above reticle Dr Bradley found his observations embarrassed by the crossing of all the wires at *i*, which hid the preceding star at the very point where it was required to be most distinctly seen.[1] He therefore proposed the construction shown in the annexed figure, where the wires *hg*, *ki* intersect one another perpendicularly at *f*, the centre of the rings. Two slender bars of brass *lg*, *ng* are fixed to the ring *abc*, and inclined each to the diameter *hg* 26° 34′, half the angle of a rhomb whose greater diagonal is double of the lesser. Hence *fk* and *fi* will be each one half of *fg*, $ki = fg$, and $fm = nl - ik$. To avoid the inconvenience of turning the telescope about its axis, Dr Bradley placed the ring *abc*, which carries the wires or brass bars in a groove in the fixed ring ABC, and confining it laterally by three pieces of brass at A, B, and C, he employed an endless screw DEF to work in a toothed rack *de*, fixed to the inner ring *abc*. Let us now suppose the telescope so directed that a star is at *f*, and moving in any line *fq*; then, by turning the milled head D, the wire *fk* will move round *f* till it touches the star at *q*, and will then lie in the direction of the star's motion, while all other stars will move parallel to it. The mode of obtaining accurate results from this apparatus will be understood from the following description of an analogous contrivance described by Lacaille.

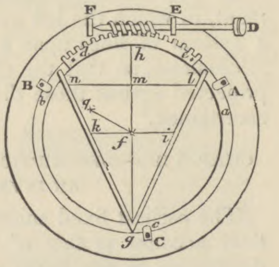

Fig. 43.

Lacaille's reticle. This eminent astronomer used a rhomb FMIL, the diagonals of which, FI, ML, must be exactly perpendicular to one another, and as two to one. The length FI was 15·4 lines, the angle subtended by $ML = 1° 25' 5''$, and consequently $FI = 2° 50' 10''$, as determined by the passage of several of the equatorial stars. Now, as the vertical height of each triangle in the rhomb is equal to the short diagonal, the path of any star passing through the field in a line parallel to that diagonal will always cut off a similar triangle, and the distance of this path from the common apex will have the same ratio to the vertical height of the large triangle, one-half FI, or ML, that the value of the diagonal in time has to the observed time of the passage. Hence the time which any star takes to pass from *m* to *l*, reduced to degrees, and multiplied by the cosine of the declination, is the difference of declination required. The difference of right ascension is obtained as before. With this simple apparatus Lacaille observed the comparative right ascensions and declinations of the 1942 stars which are given in his *Cœlum Australe Stelliferum*. Lacaille constructed another reticle in which ML was one-fourth of FI.

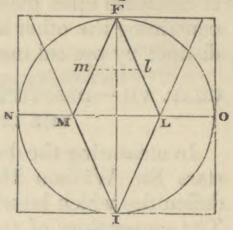

Fig. 44.

Rev. Mr Wollaston's reticle. Mr Wollaston employed a reticule similar to that shown in figure 45, AB being the horary line, and CD the equatorial line. The four squares being within the field, any of them may be used separately, so that observations made successively in a pair of them will check each other as well as the principal observation made in the large right-angled triangle. As the diagonals are equal to one another, they afford a larger passage of a star, and thus increase the accuracy of the observation.

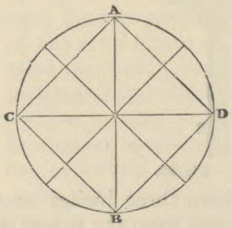

Fig. 45.

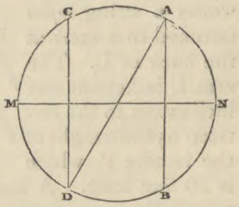

Fig. 46.

M. Valz's reticle. M. Valz[1] of Nismes has proposed the reticle shown in fig. 46 as possessing several advantages over others. It consists of three wires AB, CD, AD, and the equatorial one MN perpendicular to AB, CD. The arches AC, CM, MD, DB, &c., are all 60°. When the stars pass parallel to the equator, the angle formed at the vertex A or B will be 30°, and its cotangent $= \sqrt{3} = 1{\cdot}732$; therefore, calling t the time of passage of one star from the first to the second wire, and t' that of the other star, the difference of declination will be $1{\cdot}732\ (\pm t \pm t')$, and the difference of right ascension will be had from the times of the stars passing the middle of the space between CD and AB, or the means of the times of passing CD and AB. Baron Zach observes that this reticle requires no illumination, that the values of its lines do not require to be known, and that it may be used out of exact adjustment to the parallel of declination, as the corrections for such want of adjustment are easily computed.

Fraunhofer's net-micrometer. The fixed net-micrometer of Fraunhofer is shown in fig. 47. The vertical and oblique lines shown in the figure are cut upon glass with fluoric acid or diamond, and the plate has a circular motion in its cell. These lines are illuminated by light passing through the eye-tube and falling on their cut edges, so that no light passes down the tube. The lines parallel to *ef* are adjusted perpendicular to a circle of declination, and in that position the oblique light of the lamp

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[1] In the photographic form of this micrometer this evil is completely removed by leaving the point of intersection transparent, so as to form a minute circular space.

[1] Zach's *Correspondance Astronomique*, tom. i., p. 353.

Fixed Micrometers.

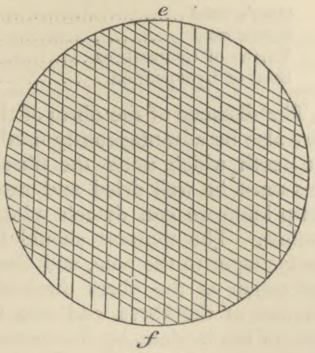

Fig. 47.

illuminates both the vertical and inclined lines. The mutual distances both of the vertical and inclined lines are known from the machine by which they were drawn, and hence the ratio of the times of transit of a star from the vertical to the inclined lines will enable us to determine the position of these in reference to a circle of declination. "The great number of lines," says Dr Pearson, "afford the means of making several observations, which on an average will give right ascensions and declinations equally exact, whether the differences of declination be great or small. When the difference of right ascension is small, as in the case of double stars, the transit of both stars cannot well be observed over the same individual line, but one of them may be observed at the first, and the other at the second line, alternately, till the observe is satisfied with his observation; and should the network experience an alteration of position from any cause, it will in all probability be detected before the computation is commenced. The ingenious artist contrived an engine by which he could cut straight parallel lines at distances so small as $\frac{1}{10000}$ of an inch from each other, and to be crossed by other parallel lines at any given angle of declination; and in the net-micrometer he formed the parallel lines at such a distance from each other, that the inclined intervals bear the same proportion to the vertical intervals that the cosine of the angle of inclination bears to radius, so that about as many transits will take place over the inclined as over the vertical lines. Five lines only are drawn at equal distances from each other, and the sixth line, including the fifth interval, is cut at the distance of one interstice and a half; yet the whole value of any number of intervals may always be known, provided it be noticed how many of the larger kind are included in the whole number. When the cell containing the disc is attached to a revolving graduated circle, the position of a line uniting two stars may also be measured by first adjusting *zero* to the equatorial position of the line *ef*, and then turning the divided disc round till all its parallels successively receive both the stars at the same instant as they pass through the field, which contemporary ingresses may be effected by repeated adjustments and subsequent trials, when the telescope is mounted on an equatorial stand properly rectified.[1] To net-micrometers of this kind, consisting of vertical and oblique lines, the method of photographically obtaining a small system upon collodion from a large one on paper is particularly applicable. (See chap. i.)

Fraunhofer's concentric circle micrometer. Another micrometer of Fraunhofer's is shown in fig. 48, and consists of concentric circles cut upon glass, and illuminated like the preceding one. The inner and smallest circle is like a dot. Other five circles are seen in a telescope of 5 feet focal length, magnifying 110 times. With a power of 63, eight circles are visible; and with the lowest power of 45, eleven circular lines are visible. The observer may choose any circle he likes for observing the passage of the star, avoiding those in which it would pass near the centre or near the circumference. The observation, too, may be made with more rings than one. The following are the dimensions of the circles in one of these instruments:—

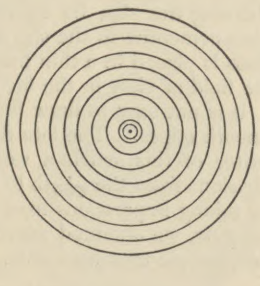

Fig. 48.

	Diameter in Paris inches.		Diameter in Paris inches.
Circle 1.	·0038	Circle 7.	·4426
2.	·0243	8.	·5264
3.	·0840	9.	·6338
4.	·1678	10.	·7178
5.	·2513	11.	·8012
6.	·3590		

By subtracting these numbers from one another we obtain the breadths of the spaces between the rings.

Fraunhofer's suspended circular micrometer. Fraunhofer's suspended annular micrometer, which is a more perfect instrument than the preceding, is shown in fig. 49, which represents a disc of glass, having a hole in its centre a little larger than the inner diameter of a metallic ring RR, turned truly in a lathe. This ring is cemented on the glass disc, and when placed in the field of view of a telescope, the observer notes the instants when a star or the limb of a planet enters and emerges from each side of the ring. The only data required for computing the difference of right ascension and declination are the times that an equatorial star takes to pass along the internal and external diameters of the ring. The passage of stars whose relative position is required, must be observed at a distance from the centre, as well as from the upper edge of the ring. Admiral Smyth mentions, that in one of these instruments which he possesses he found, by repeated measurements of stars near the ecliptic and on the meridian, that the radius of the ring was 472·5 seconds in arc.[1] The formulæ of Bessel for using this and other circular micrometers will be found in Zach's *Monatliche Correspondenz*, vol. xvii., xxiv., and xxvi.

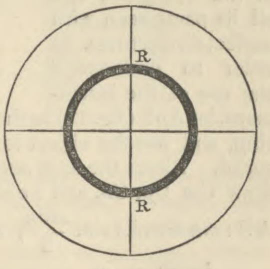

Fig. 49.

Photographic annular micrometer. An annular micrometer, with one or more rings of different diameters and breadths, may be advantageously formed photographically upon collodion by the process already described. By reducing large rings formed by black ink and fine compasses,[2] a more correct circular edge may be obtained than by the turning lathe. Luminous rings may be formed of such extreme narrowness that the star will, as it were, leap through the interval in passing across the field of the telescope. (See chap. i.)

Cavallo's mother-of-pearl micrometer. A simple and useful fixed micrometer, proposed by Mr Cavallo, is a divided slip of thin mother-of-pearl stretching across the diaphragm of the telescope, and finely divided into 200ths of an inch. It is shown in fig. 50 crossing the diaphragm of the telescope. The value of the division may be ascertained either by measuring a bar, or by the passage of an equatorial star across the field of view.

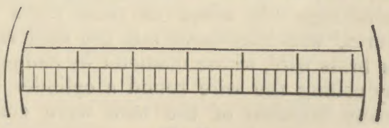

Fig. 50.

In a portable telescope this micrometer is very convenient, though it has the great disadvantage of shutting out the field of view. In telescopes upon stands it will measure only angles in one direction, unless there is a contrivance to turn it round. This micrometer has also the additional imperfection that its divisions, from being unequally distant from the eye-glass, are not all seen with the same distinctness.

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[1] *Introduction to Practical Astronomy*, vol. ii., p. 143.

[1] *Celestial Cycle*, vol. i., p. 339, note.

[2] The outer and inner margins of a ring having been formed with fine compasses, the interval may be filled up by the blackest ink.

Fixed Micrometers.

Circular mother-of-pearl micrometer.

To remove these imperfections Sir David Brewster proposed in 1805 the circular mother-of-pearl micrometer, which is shown in fig. 51, where the black ring which forms part of the figure is the diaphragm of the telescope, and the more luminous part is an annular portion of mother-of-pearl divided on its inner circumference into 360°. This divided circumference can be placed exactly in the focus of the eye-glass, and all its parts seen with perfect distinctness. In order to understand the use of the instrument, let A*p*B (fig. 52) be the inner edge of the mother-of-pearl ring, and *mn* the object to be measured. Bisect the arch *mn* in *p*, and draw C*m*, C*p*, C*n*, and we shall have $\mathrm{AB} : mn = \mathrm{rad.} : \sin. \frac{mpn}{2}$, and $mpn = \sin \frac{\frac{1}{2}mpn}{\mathrm{rad.}} \times \mathrm{AB}$, a formula by which the angle subtended by the chord of any number of degrees may be readily found. The first part of the formula is constant, while AB varies with the magnifying power employed.

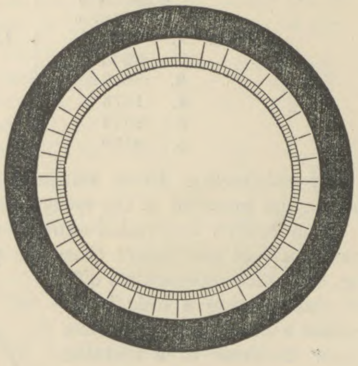

Fig. 51.

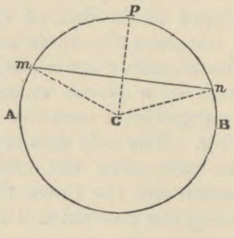

Fig. 52.

CHAP. IX.—DESCRIPTION OF MICROMETERS FOR MICROSCOPES.

Micrometers for microscopes.

All the micrometers above described may be adapted to compound microscopes where the eye-glass has a considerable focal length. A good micrometer, however, for single microscopes, which can be used with facility, and at the same time give accurate results, is still a desideratum. When the single lens is so minute, or when the first lens of a microscopic doublet or triplet almost touches the surface of the object, it is an extremely difficult matter to introduce any scale, or any minute body of known dimensions, with which the object may be compared. In some cases, when the object to be measured is minute, the seed of the *Lycoperdon bovista* or *puff-ball* might be introduced, its diameter being about the $\frac{1}{8500}$th part of an inch; and when the object is less minute, the seed of Lycopodium may be used, its diameter being $\frac{1}{940}$th of an inch. We may advantageously adopt in some cases the method of Dr Jurin,[1] who introduced into the field small pieces of silver or brass wire, whose diameter he had previously ascertained by coiling the wire round a cylinder, and observing how many breadths of the wire were contained in a given number of inches.

This method of introducing a substance of known dimensions may be carried much farther. We may use all the variety of hairs and wool which have a known diameter; and for this purpose Dr Young's tables of substances measured by the eriometer will be of great use. The following are a few of them:—

	Diameter in parts of an inch.	
Lycoperdon bovista, seed of	8500th	of an inch.
Smut of barley	4600th	...
Silk, fibre of (average)	2500th	...
Human blood, particles of (*Bauer*)	2500th[2]	...
Mole's fur	1875th	...
Goat's wool	1575th	of an inch.
Saxon wool	1320th	...
Farina of Laurestinus	1100th	...
Seed of Lycopodium	940th	...

Micrometers for Microscopes.

The distance of the fibres of the crystalline lens of fishes may also be advantageously used, and also the distance of the teeth which unite the fibres. For this purpose the lens must be well dried and perfectly hard, so that with a sharp knife we can detach minute portions of any of the laminæ. The thinnest should be used; and as the fibres always taper to the pole, and the teeth become smaller in proportion as the fibres diminish, we must determine the distance of the fibres, and also those of the teeth, at both ends of the laminæ, by the method described by Sir David Brewster in the *Philosophical Transactions* for 1833, p. 324. The larger lined scales of moths and butterflies may also be used, especially as we can measure the distance of the lines by the coloured spectra which these lines produce.[3] These operations will require much dexterity on the part of the observer, and they are recommended only to those who cannot succeed in their measurements by other methods.

An excellent method of measuring microscopic objects is to project the image of the object against a divided scale at a given distance from the eye. The scale must be seen either by the same eye which is looking into the microscope, or by the other eye. In the first case the rays from the microscope will enter one side of the pupil, and the rays from the divided scale the other side; the aperture through which we look at the scale, and the aperture of the microscope, being at a distance less than the diameter of the pupil. When the right eye looks at the divided scale, the left, which looks into the microscope, will see the object projected against the scale, although it has no vision of the scale itself. This second method may be carried into effect in two ways. The scale may form no part of the instrument, and may be viewed by the naked eye; or it may form part of the instrument, like a binocular telescope, the left eye looking into one tube, viz., the microscope, while the right eye looks into another tube, in which a divided scale is magnified by an eye-lens.

The earliest micrometer of any value is the *Stage Micrometer* of Mr Coventry, which consists of a number of very fine lines ruled with a diamond point upon slips of glass, metal, ivory, or mother-of-pearl. These lines were drawn at various distances, from the $\frac{1}{100}$th to the $\frac{1}{1000}$th of an inch, and upon the slip thus formed the object to be measured was placed. The object and the lines being seen at the same time, the number of linear spaces covered by the object gives its magnitude in the parts of an inch corresponding with the distance of the lines. As these lines are not easily seen, Mr George Jackson renders them visible by rubbing into them very finely levigated plumbago, and in order to prevent the plumbago from being wiped out in cleaning the slip, he covers the lines with a thin piece of glass cemented to the slip by Canada balsam. The slip of glass is placed in a thin frame of brass, and is moved across the field of view in the focus of the eye-glass by a screw.

It is not easy to draw fine lines upon glass so as to have smooth edges. The late Sir John Barton executed for the writer of this article a variety of slips of steel containing divisions from the $\frac{1}{500}$th to the $\frac{1}{10000}$th part of an inch; and by taking impressions from these upon transparent films of gelatine, we obtained micrometer slips of great utility for microscopic measurements. M. Froment of Paris has exe-

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[1] *Physico-Mathematical Dissertations*, p. 45.

[2] We consider this the best measure.

[3] The late Mr Pond has observed, that the pale, slender, double-headed scales of the *Pontia* or *Pieris brassica*, which taper to a point, and terminate in a brush-like appendage, are of an invariable length, about $\frac{1}{80}$th of an inch.

Micrometers for Microscopes.

cuted divisions upon glass surfaces exceedingly minute and singularly fine.

Photographic scale.

The mode of executing a system of black parallel lines photographically upon transparent collodion, already described (chapter i.), has a particular value in microscopical measurements. The collodion in thin plates is as transparent as glass, even under very high powers, and the lines are absolutely black and smooth at the edge. Circular spots of the minutest size can be formed in a similar manner, so as to enable us to compare with them similar microscopic objects, such as the discs of blood; and small angular spaces, opaque and transparent, with divisions along the lines which contain the angle, may be advantageously used in microscopical micrometry.

Ross's eye-piece micrometer.

Mr Ross's eye-piece micrometer consists of circular discs of glass divided into small squares, as shown in the annexed figure. This system of squares, which may be finely executed upon collodion, is placed in the focus of a positive eye-glass or between the lenses of a negative one. When the divisions on the slips of glass are covered with the thinnest glass cemented to the slip, the object and the division are not exactly in the same plane; but, excepting in the use of high powers, this is of little importance, as both the object and the lines are seen with sufficient distinctness for the purpose of measurement.

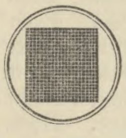
Fig. 53.

Dr Wollaston's lens-micrometer.

Dr Wollaston has constructed and used a very ingenious micrometer on the first of the principles above mentioned, viz., when the object and the scale are viewed by the same eye; but its use is limited to microscopes with small lenses. When the lenses are larger we have adopted another method, namely, to perforate the lens with a small hole in or near the centre, or, if it is thought better, near the margin of the lens. A slit extending from the margin of the lens may often be executed more easily.

The following is Dr Wollaston's own description of this instrument:—

"This instrument," says Dr Wollaston, "is furnished with a single lens of about $\frac{1}{12}$th of an inch focal length. The aperture of each lens is necessarily small, so that when it is mounted on a plate of brass, a small perforation can be made by the side of it in the brass, as near to its centre as $\frac{1}{25}$th of an inch.

"When a lens thus mounted is placed before the eye for the purpose of examining any small object, the pupil is of sufficient magnitude for seeing distant objects at the same time through the adjacent perforation, so that the apparent dimensions of the magnified image might be compared with a scale of inches, feet, and yards, according to the distance at which it might be convenient to place it.

"A scale of smaller dimensions attached to the instrument will, however, be found preferable on account of the steadiness with which the comparison may be made; and it may be seen with sufficient distinctness by the naked eye, without any effort of nice adaptation, by reason of the smallness of the hole through which it is viewed.

"The construction that I have chosen for the scale is represented in fig. 54. It is composed of small wires about $\frac{1}{60}$th of an inch in diameter, placed side by side so as to form a scale of equal parts, which may be with ease counted by means of a certain regular variation of the lengths of the wires.

"The external appearance of the whole instrument is that of a common telescope consisting of three tubes. The scale occupies the place of the object-glass, and the little lens is situated at the smaller end, with a pair of plain glasses sliding before it, between which the subject of examination is to be included. This part of the apparatus is shown separately in fig. 55. It has a projection, with a perforation, through which a pin is inserted to connect it with a screw, represented at *b* (fig. 56). This screw gives lateral motion to the object, so as to make it correspond with any particular part of the scale. The lens has also a small motion of adjustment, by means of the cap *c* which renders the view of the magnified object distinct.

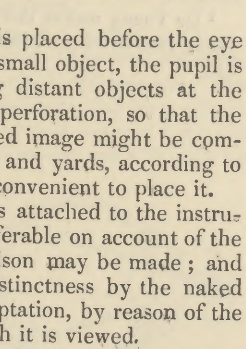
Fig. 54.

Micrometers for Microscopes.

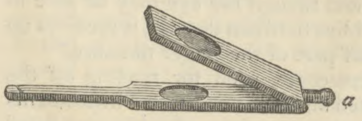

Fig. 55.

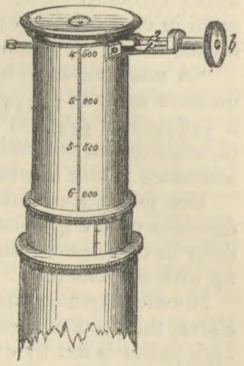

Fig. 56.

"Before the instrument is completed, it is necessary to determine with precision the indications of the scale, which must be different according to the distance to which the tube is drawn out. In my instrument one division of the scale corresponds to $\frac{1}{10000}$th of an inch when it is at the distance of 16·6 inches from the lens; and since the apparent magnitude in small angles varies in the simple inverse ratio of this distance, each division of the same scale will correspond to $\frac{1}{5000}$th at the distance of $8\frac{3}{10}$ inches; and the intermediate fractions $\frac{1}{6000}$th, $\frac{1}{7000}$th, &c., are found by intervals of 1·66 inch, marked on the outside of the tube. The basis on which these indications were founded in this instrument was a wire, carefully ascertained to be $\frac{1}{200}$th of an inch in diameter, the magnified image of which occupied fifty divisions of the scale when it was at the distance of 16·6 inches; and hence one division $=\frac{1}{50\times 200}=\frac{1}{10000}$. Since any error in the original estimate of this wire must pervade all subsequent measures derived from it, the substance employed was pure gold drawn till 52 inches in length weighed exactly five grains. If we assume the specific gravity of gold to be 19·36, a cylindrical inch will weigh 3837 grains; and we may hence infer the diameter of such a wire to be $\frac{1}{200}$th of an inch, more nearly than can be ascertained by any other method.

"For the sake of rendering the scale more accurate, a similar method was, in fact, pursued with several gold wires of different sizes, weighed with equal care; and the subdivisions of the exterior scale were made to correspond with the average of their indications.

"In making use of this micrometer for taking the measure of any object it would be sufficient, at any one accidental position of the tube, to note the number on the outside as denominator, and to observe the number of divisions and decimal parts which the subject of examination occupies on the interior scale as numerator of a fraction, expressing its dimensions in proportional parts of an inch; but it is preferable to obtain an integer as numerator, by sliding the tube inward or outward, till the image of the wire is seen to correspond with some exact number of divisions, not only for the sake of greater simplicity in the arithmetical computations, but because we can by the eye judge more correctly of actual coincidence than of the comparative magnitudes of adjacent intervals. The smallest quantity which the graduations of this instrument profess

Micrometers for Microscopes.

to measure is less than the eye can really appreciate in sliding the tube inward or outward. If, for instance, the object measured be really $\frac{1}{9900}$, it may appear $\frac{1}{10000}$, or $\frac{1}{9800}$, in which case the doubt amounts to $\frac{1}{50}$th part of the whole quantity. But the difference is here exceedingly small in comparison to the extreme division of other instruments, where the nominal effect of its power is the same.

"A micrometer with a divided eye-glass may profess to measure as far as $\frac{1}{10000}$th of an inch; but the next division is $\frac{2}{10000}$th or $\frac{1}{5000}$th; and though the eye may be able to distinguish that the truth lies between the two, it receives no assistance within one-half part of the larger measure."[1]

The micrometer microscopes used for reading off the divisions on the graduated limb of astronomical instruments differ in no respect from the eye-pieces of telescopes fitted up with micrometers.

Notwithstanding the value of the methods described above, the want of a simple micrometer for microscopes of high power is felt by every person who has been practically occupied with this class of researches; and we cannot give a better proof of this than by adducing, in support of our opinion, the different measures that have been given by able and ingenious observers of the size of the particles of the human blood:—

Dr Thomas Young	1-6060th	part of an inch.
Dr Wollaston	1-5000th	...
MM. Prevost and Dumas	1-4076th	...
Captain Kater	1-4000th	...
M. Ehrenberg[2]	1-3600th	...
Messrs Hodgkin and Lister	1-3000th	...
Sir David Brewster	1-2556th	...
Dr Jurin[3]	1-1940th	...
Mr Bauer's best observation	1-2500th	...
next best	1-2000th	...
worst observation	1-1000th	...

The three measures of 1000, 2000, and 2500, were given by Mr Bauer himself, as the different steps which he made towards what he conceives the best measure, viz., 1-2500th, which he obtained repeatedly with an improved achromatic microscope. As Dr Young obtained his measure *eriometrically*, namely, by measuring the diameter of the first red ring produced by looking through the blood at a luminous object, we cannot conceive it possible that he could have committed such a mistake as to make the diameter of that ring nearly *thrice as great* as it should be, according to Mr Bauer's results, or more than thrice as great as the concurring measures obtained by Jurin and Leewenhoeck. The only explanation we can give is, that the particles of the blood must have an organized structure, or consist of portions separated by lines which have the magnitude assigned by Dr Young. In order to submit this explanation to the test of experiment Sir David Brewster examined the particles of blood a few minutes after it was drawn, when dried by natural evaporation on a plate of glass. Each particle he found to consist of a dark rim, within which is a bright circle, then a darkish central spot, which spot in some globules may be resolved into a dark ring, a bright ring within this, and then a small central black spot. Here, then, is the cause of Dr Young's mistake. The red ring of light which he measured in the eriometer was not that which was due to the globule as a whole, but to the parts of the globule. Being anxious to obtain more complete evidence of this fact, we placed Lycopodium powder beside the globule of blood, and found that the diameter of the globules was to that of the Lycopodium seed as 5 to 18. We then compared the diameter of the red ring produced by the seed with the diameter of the red ring produced by division on steel, in which there were 1250 to the inch, as executed for us by the late Sir John Barton, and found the diameter of the seed to be the 697th of an inch. We compared it also with the ring produced by divisions of which there were 625 to the inch, and found its diameter the 717th part of an inch. The mean of these two is the 710th[1] part of an inch, which, increased in the ratio of 5 to 18, gives the 2556th part of an inch as the measure of the diameter of the globules of blood, agreeing almost exactly with the measure of Mr Bauer.

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[1] *Phil. Trans.*, 1813, p. 119.

[2] In measuring the size of the fossil infusorias discovered by himself, M. Ehrenberg assumes a globule of human blood to be $\frac{1}{300}$th of a line in diameter, or $\frac{1}{3600}$th of an inch, but of what inch is not mentioned. He does not state whether this measure is taken by himself or not. He reckons the thickness of a human hair at $\frac{1}{48}$th of a line at its mean thickness, or $\frac{1}{567}$th of an inch.

[3] This result was confirmed by Leewenhoeck, who used the same wire, which was sent to him by Dr Jurin. (*Phil. Trans.*, No. 377.)

[1] Dr Young makes this the 940th of an inch, but he has certainly committed a mistake in his observation.

MICROSCOPE.

MICROSCOPE, from μικρος, a *small object*, and σκοπεω, to *see* or *examine*, is the name of a well-known optical instrument for examining and magnifying minute objects, or the minute parts of large ones. Dr Goring has, in his various works on the microscope, used the word *engiscope*, from εγγυς, *near*, and σκοπεω, *to see;* but the old and venerable term is so associated with the history of optical discovery, and is so expressive of the application of the instrument, that we cannot consent to the proposed change.

Single microscopes, in the form of glass globes containing water, were used by the ancients. A magnifying lens of rock-crystal was found by Mr Layard among a number of glass bowls in the north-west palace of Nimroud. Hemispheres of glass, and afterwards lenses, were subsequently used, so that no person has pretended to claim the invention of the single microscope. The compound microscope, consisting of two lenses placed at a distance, so that the one next the eye magnifies the enlarged image of any object placed in front of the other, was invented by Zacharias Zansz, or his father Hans Zansz, spectacle-makers at Middleburg in Holland, about the year 1590. One of their microscopes, which they presented to Prince Maurice, was in the year 1617 in the possession of Cornelius Drebell of Alkmaar, who then resided in London as mathematician to King James VI.

There is probably no branch of practical science which has undergone such essential and rapid improvements as that which relates to the microscope. It has become quite a new instrument in modern times, and it promises to be the means of disclosing the structure and laws of matter, and of making as important discoveries in the infinitely minute world as the telescope has done in that which is infinitely distant.

CHAPTER I.

ON SINGLE MICROSCOPES.

Single microscopes.

When only one convex lens AB (fig. 1) is used for magnifying objects, the lens is called a single microscope. The object *mn* to be examined is placed before the lens AB, in its anterior focus; so that the rays which emerge from the lens after refraction by the humours of the eye CD may be parallel, and a distinct and enlarged image MN of the object *mn* formed on the retina. The simplest form of the single microscope is when the lens is fitted into a rim of brass furnished with a handle, so that when the object is held in the left hand and the lens in the right, it may be examined with facility. If the convex lens is very minute, and has a short focal length, such as from the 10th to the 100th of an inch, it cannot be conveniently used in the hand, and must therefore be either connected with an arm to hold the object, or placed in a firm microscope stand, having a shelf or stage for the object, a screw or a rack and pinion for placing it in the focus of the lens, either by moving the object or the lens, and a larger lens or mirror, or both, for throwing light upon the object. In this form, however complex be its structure, it is still called a single microscope.

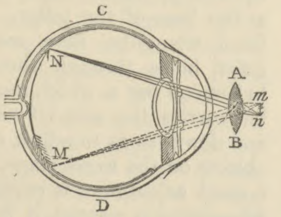

Fig. 1.

The lens which constitutes a single microscope, in order to have all the excellence which art can give it, must consist of a substance perfectly homogeneous, like a fluid without double refraction, or any variation of density. Its figure ought to be that of a plano-convex lens, whose convex surface is part of a hyperboloid, in order to correct completely the spherical aberration. Its surface should be perfectly smooth and highly polished, so as not to disturb the perfection of vision; and the substance of which it is made should have the lowest dispersive power. As it is a great object to obtain high magnifying powers with as little convexity as possible, and a large aperture, substances with high refractive and low dispersive powers are the most suitable for single lenses, such as diamond or garnet, which have no double refraction when well crystallized; or such as ruby, sapphire, topaz, &c., which have double refraction. As fluor spar has the lowest dispersive power, it might be used with great advantage when high powers are not wanted, and when the diminution of colour is an object.

Of all the substances we have named, fluids have properties best suited for single microscopes. They possess perfect homogeneity; their surfaces, when made into lenses, are perfectly smooth; and it is possible to mould minute drops of them into a form approaching to that of the hyperboloid. Their defect, however, consists in their not having a high refractive power, in their want of durability, and the difficulty of forming sufficiently minute lenses for producing high magnifying powers. These defects, however, may be overcome by patience and experience; and in proof of this we may state that we have succeeded in forming minute fluid lenses of great excellence.

In the present state of this branch of science, it would be unprofitable to detail the methods of producing microscopic globules of glass, given by Dr Hooke, Father di Torré of Naples, Mr Butterfield, or Mr Sivright; because when they are made after their methods, and in the most perfect manner which these methods will permit, they are of no value compared with lenses of glass when ground and polished to the same focal length.[1]

We shall therefore proceed to describe a single microscope when fitted up in the best form for observation.

Description of a Single Microscope.

Single microscope.

The most essential part of this instrument is the lens or lenses, upon which the value of the microscope depends. The lenses are generally made of plate-glass, and should have focal distances varying from the $\frac{1}{10}$th to the $\frac{1}{60}$th of an inch. In order that the spherical aberration of these lenses may be the smallest possible, the radii of their two surfaces, when made of plate-glass, should be as 1 to 6; the surface whose radius is 1, or the most convex side, must be turned towards the eye. The lenses thus made are then set in the centre or the lower surface of concave brass caps, a section of one of which is shown in fig. 2.

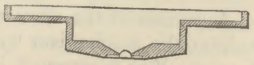

Fig. 2.

Pritchard's microscope.

One of the best modes of fitting up the single microscope is that contrived by Mr Pritchard, which is represented in fig. 3, on a scale about one-third of its real size. It is shown in an inclined position; but it may be used either in a vertical or a horizontal one, according to the convenience of the observer. The body of the instrument rests on a pillar *b*, supported by three legs, shown at *a*, and is connected with it by the clip *f*, being fixed by the pinching screw *f*. Within the tube *c* there slides a tube *h*, connected by a screw which passes through it to the triangular tube or bar *i*, carrying the arm *ij*, into which is placed the brass cap *j* which carries the lens. This lens is adjusted to the distinct vision of objects placed on the stage *l*, by sliding the tube *h* up or down, and a perfect adjustment is obtained by turning the milled head *k*. The stage *l*, which carries the objects, is fitted into the triangular box *r* at the extremity of the stem, by means of two pins, and can be removed at pleasure. The spring slider-holder, for holding the sliders in which the objects are placed, is fixed by a bayonet-joint into the stage; and it may be used to hold stops or diaphragms for limiting the field of view. The tube above *f* represents an illuminator fixed to the slider-holder. Upon the tube *c*, two sockets *d*, *e*, slide with sufficient spring and friction to keep them in their place. The socket *d* carries the reflector *d*, and the socket *e* carries the condensing lens, which is not inserted in the figure.

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[1] These methods may be found by the following references:—Hooke's *Micrographia;* Di Torré, *Phil. Trans.* 1765, p. 246, 1766, p. 67; Butterfield, *Phil. Trans.*, 1678; Sivright, *Edin. Phil. Journal*, 1829, vol. i., p. 81.

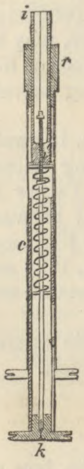

Fig. 4.

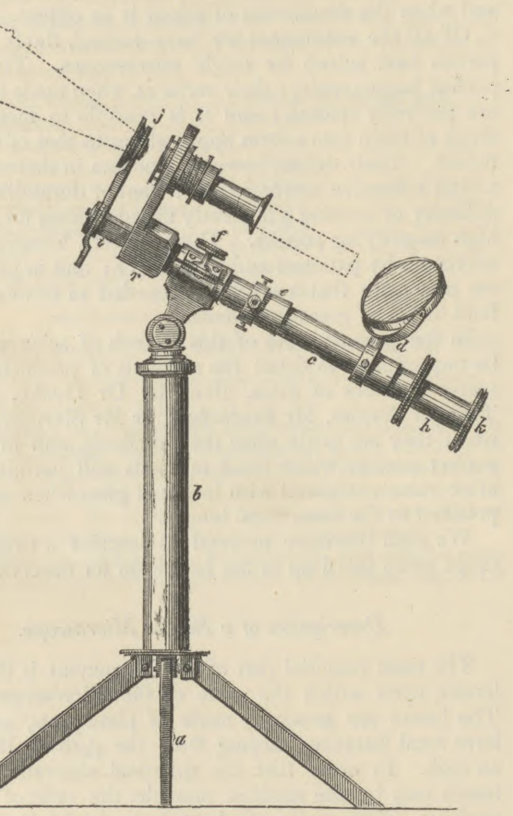

Fig. 3.

A section of the stem *rck* is shown in fig. 4, in order to exhibit the mechanism by which the adjustment is effected. Into the box *r*, screwed into the top of the stem, is fitted the triangular tube *ii*, which carries the arm *ij*. In the lower end i' of this triangular tube is a small block with a fine screw working in it, the stem of which turns along with the milled head *k* to which it is fixed. The upper end of a spiral spring, shown in the figure, bears against the block i' at the bottom of the triangular tube, while its lower end acts against a stop fixed within the sliding tube *h*. The method of managing, illuminating, and examining opaque objects with this microscope is the same as that used in the achromatic compound microscope, in the drawing of which it will be more distinctly seen.

The preceding instrument of Mr Pritchard's is intended for general purposes; but as the dissection of botanical and other objects is now a leading object with naturalists, we shall add an account of another microscope, constructed in 1831 by Mr A. Ross, with much skill, for Mr W. Valentine of Nottingham, an eminent vegetable anatomist, who succeeded in dissecting with it under a lens of $\frac{1}{20}$th of an inch in focal length.[1]

Ross's microscope.

A perspective view of this microscope is shown in fig. 5. It is supported on a closing tripod *aaa*, whose feet can be folded together, and are made of hard bell-metal, prevented from springing by edge bars, as seen on the left-hand foot. A firm pillar, which rises from the tripod, carries the stage *x*, which is fixed on brackets, to give a steady support to the hands of the operator. A capital, fixed to the top of the tube by three screws, has in its axis a triangular hole, into which is fitted a triangular tube, the lower end of which passes through another similar triangular tube fixed to the inside of the instrument. The triangular tube is made to slide up and down by a fixed screw, wrought by a large milled head, which is most judiciously placed at the base of the pillar. At the top and bottom of the fixed triangular tube are fitted two pieces, with triangular holes through them for receiving the triangular bell-metal bar *s*, which moves up and down in them. This bar carries the arm 10 with the lenses. It is moved up and down, so as to adjust the lenses to distinct vision of the objects on the fixed stage, by the rack and pinion *t*, when a quick adjustment is required; but when a slow and nicer adjustment is wanted, it is effected by the milled head *o*. A slit is made in the shaft of the pillar, to allow the neck of the small milled head *t* to move up and down; for when the screw is in action by the large milled head *o*, the triangular tube and the bar move together. The triangular bar is perforated at both ends,—the upper perforation for receiving a conical pin, and the lower for admitting the adjusting screw to preserve the length of the bar. The bearings of the pinion *t* are attached to the triangular tube. The bar moves $1\frac{1}{2}$ inch, and the tube $1\frac{1}{2}$, so that

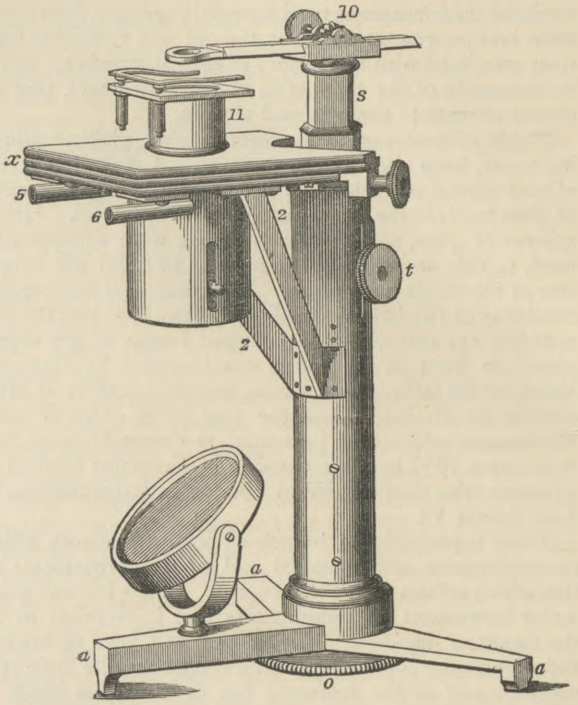

Fig. 5.

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[1] See *Transactions of the Society of Arts*, vol. xlviii., where a full description of this microscope, with drawings of all its parts, will be found.

we can command an elevation of 3 inches. At the ingenious suggestion of Mr Solly, the screw moved by the milled head *o* has fifty threads in an inch, and the milled head is graduated into 100 parts, for the purpose of measuring the thickness of any vessel or other object in the direction of the axis of vision. For this purpose the upper surface of the body is brought into distinct vision; the division at which the index or pin of the tripod stands is then observed; and the under surface being in like manner brought into focus by turning the milled head *o*, the division is again observed. The number of divisions, which are each 5000ths of an inch, between these two numbers, *will indicate*, according to Mr Valentine, *the space through which the lens has passed, which is the diameter of a vessel.*[1]

In this microscope different parts of an object may be brought into the field, either by moving the stage or the lens; a very important requisite in a microscope used for the purposes of discovery. With this view, the large stage *x* is formed of three plates, the lowest of which is fixed to the pillar by the ring 1; and, to make it bear the weight of the hands, it rests upon the strong brackets 2, 2. The under side of this plate is shown in fig. 6; the middle plate (fig. 7) contains two pairs of dovetail slits, 3, 3 and 4, 4, the widest orifice of each being on opposite sides of the plate. The dovetail pieces in 4, 4 screw into the upper side of the upper plate (fig. 8), the points of the screws being shown at 4, 4 in that figure; while the dovetail pieces in 3, 3 are secured to the upper side of the under plate by the screws 3, 3 (fig. 7). The plates are thus moved diagonally, and at right angles to one another, by the adjusting screws 7 and 8 (fig. 8). In the adjusting screw 7 the ball is placed in spring couplings, and fastened to the under side of the upper plate. These screws are judiciously placed, one on each side of the pillar, that the hand may reach them easily and not intercept the light. By turning first one screw, and then the other, or both at once, any part of the object may be brought into the field.

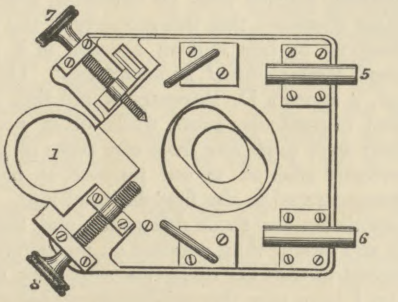

Fig. 6.

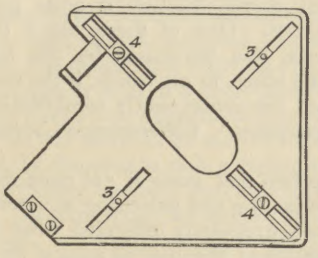

Fig. 7.

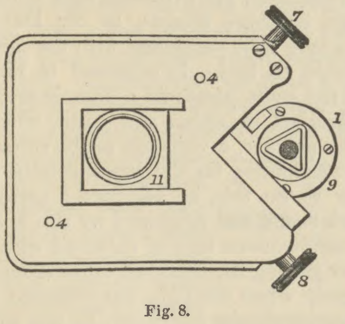

Fig. 8.

The arm for holding the lenses is shown at 10 (fig. 5). A conical pin projects from underneath, and fits into a hole made down the triangular bar, as shown at 9 (fig. 8). The lens will therefore have a circular movement in a horizontal plane, and it may be placed at any point in this plane by the action of the rack and pinion at 10. Hence the most complete adjustment can be obtained without any motion of the stage.

The elevated stage for holding the objects is shown at 11 in figs. 5 and 8. A tube screws into the upper plate, and upon this fits the tube 11, carrying the finger-spring, shown in fig. 5. Objects of different thickness are thus kept down upon the plates by the pins sliding in the small pipes. A condensing lens and pincers slide into the sockets 5 or 6 (fig. 5).

The large reflector above *a* (fig. 5) may be removed, and any other illuminating apparatus substituted.

As the stand and apparatus now described may be used along with all single microscopes, and also with what are called doublets and triplets, we shall now proceed to give an account of the various improvements which the single microscope has undergone.

Between the single lens held in the hand and the one mounted with much of the apparatus of a compound microscope, we may place what has been called the *simple microscope*, which is nothing more than a single lens mounted on a stand, so that it may be fixed in various positions suited to the purpose to which it is to be applied.

Mr Ross's simple microscope is shown in fig. 9. It consists of a stand A, with a sliding tube which can be raised or depressed. On the top of this tubular stand is fixed a jointed socket MN, through which a square bar CD slides, carrying at one of its extremities the lens L, the ring of which moves round a joint at C. Lenses of an inch, a half-inch, and a quarter of an inch focus should accompany the instrument, which may be packed into a small space.

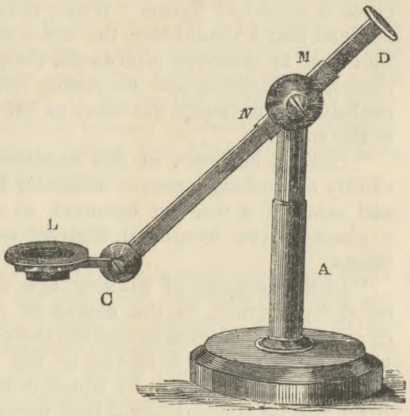

Fig. 9.

Single Microscopes made of Precious Stones.

Single microscopes of precious stones.

The low refractive power of glass rendered it necessary, when high powers were wanted, to use lenses with very short foci, and consequently with very deep curves and very small diameters, so as to admit only a narrow pencil of light into the eye.

Sir David Brewster was the first person who pointed out the value of using other materials for the construction of lenses;[1] and he remarked that no essential improvement could be expected in the single microscope, unless from the discovery of some transparent substance, which, like the *diamond*, combines a high refractive with a low dispersive power. Having experienced the greatest difficulty in getting a small diamond cut into a prism in London, he did not conceive it practicable to grind and polish a diamond lens,[1] and therefore did not put his opinion to the test of experiment. He got two lenses, however, executed by Mr Peter Hill, an ingenious optician in Edinburgh, the one made of ruby and the other of garnet, and these lenses he found to be greatly superior to any lenses that he had previously used.

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[1] This is not the case, as the refraction of the light issuing from the lower side of the vessel or object is not considered. The right mode is, after having observed the upper surface of an object lying upon glass, remove the object, and observe the divisions when the surface of the glass is seen distinctly; the difference will be the true thickness. Mr Samuel Varley is said to have constructed an instrument on this principle for measuring the thickness of foci of lenses; but unless he removed his lens after observing the first surface, his results must have been all erroneous.

[1] *Treatise on Philosophical Instruments*, 1813, pp. 402, 403.

Dr Goring, whose zeal and success in the improvement of microscopes has not been surpassed, directed the attention of Mr Pritchard in 1824 to the passages in Sir David Brewster's Treatise on New Philosophical Instruments, respecting the value of the precious stones for single microscopes; and having immediately seen their full force, it was agreed that they should undertake to grind a diamond into a magnifier.

Diamond Lenses.

Diamond lenses.

The history of this attempt is so interesting, that we must give it in Mr Pritchard's own words:—"For this purpose," says he, "Dr Goring forwarded me a small brilliant diamond to begin upon; and it was proposed to give it the curves that in glass would produce a lens of a twentieth of an inch focus. This stone I ground with the proper curves, and polished the flatter side, contrary to the expectations of many whose judgment in these matters was thought of much weight, who predicted that the crystalline structure of the diamond would not permit it to receive a spherical figure. When thus far advanced, fate decreed that I should lose the stone, and my only consolation was, to discover afterwards, that, had it been completed, its thickness and enormous refractive power would probably have caused the focus to fall within the substance of the stone.

"Having, however, in this experiment, proved the possibility of working lenses of adamant, I set about another, and selected a rose-cut diamond, in order to form it into a plano-convex lens, and thereby save a moiety of the labour.

"In the progress of working this stone the heat generated by friction, in the course of the abrasion of the diamond, was perpetually melting the cement (shell-lac) by which the flat side was affixed to the tool, and compelled me to seek some means by which it might be prevented. After several trials, I found that when a portion of finely powdered pumice-stone was mixed with the shell-lac, the cement was much stronger, and less liable to melt, than any other similar substance.

"On the 1st of December 1824 I had the pleasure of first looking through a diamond microscope, and it was doubtless the first time this precious gem had been employed in making manifest the hidden secrets of nature. A few days after, I had polished it sufficiently to put it into the hands of Dr Goring, who tried its performance on various objects, both as a single microscope and as the objective of a compound. He states in a letter addressed to me, dated 3d January 1825, 'that it has shown the most difficult transparent objects I have submitted to it;' and again, 'I can clearly perceive the amazing superiority it will possess when completely finished.' I must, however, inform my readers, that we discovered in this state various flaws in the stone, in consequence of which we abandoned all thought of completing it. In this condition the project remained for about a year, when I determined to resume my attempts; and having worked several stones into lenses, I at last succeeded in obtaining a perfect one. In the course of these labours, a new though not unexpected defect appeared in several lenses, which would have subverted the whole scheme had not the first diamond lens been free from it.

"These lenses, instead of giving a single image like the first, gave a double or triple one. This rendered them utterly useless as magnifiers, and made the defects of soft and hard parts in the same stone, and the small cavities in others, of comparatively trifling consequence. The images exhibited in such lenses overlapped each other, but were never entirely separated, though the quantity of overlapping varied in different specimens.

"It was now evident that these defects arose from polarization, though this stone is described as 'refracting single.' I subsequently learned from Dr Brewster, after I had overcome these obstacles, that this property of the diamond had been observed by him, and an account of it given in the *Edinburgh Philosophical Transactions.*[1] On referring to his paper, it appears Dr Brewster found that some stones 'polarized in particular *parts*, while other *portions of the same stone were quite free from any trace of polarity*,' and thus perfectly adapted to our purpose, as had previously been demonstrated in the first diamond lens.

"Notwithstanding these difficulties, and the consequent expense and labour they entailed on me before sufficiently experienced in working upon this refractory material with certainty, I have now the satisfaction of being able, by inspection *à priori*, to decide whether a diamond is fit for a magnifier or not; and have now executed two plano-convex magnifiers of adamant, whose structure is quite perfect for microscopic purposes. One of these, about the twentieth of an inch focus, was purchased by the late Duke of Buckingham; the other, in my hands, is the thirtieth of an inch focus, and has consequently amplification enough for most practical purposes." (*Microscopic Cabinet*, p. 107-111.)

Although it is quite certain that many if not most diamonds possess a doubly-refracting and polarizing structure, owing to their having been irregularly indurated when in a soft state, yet the separation of the images, arising from this structure, is not sufficient to account for the overlapping of the images observed by Mr Pritchard. In order to have this matter investigated, Mr Pritchard sent a bad diamond lens, with two or three images, to Sir David Brewster, who was for a long time perplexed with the difficulties which it presented to him. It occurred to him, however, to examine if the stone possessed a homogeneous structure, as he had observed in amber and gums, which are indurated in a similar manner, a variation in the refractive density capable of accounting for the imperfections of the diamond. In order to do this, he admitted a narrow beam of light into a dark room, and examined by this light the flat surface of the plano-convex lens of diamond with a hand microscope. After getting the diamond into the most favourable position, namely, when the light was reflected as nearly as possible at a perpendicular incidence, he was surprised to see its whole surface covered with thousands of minute bands, some reflecting more and some less light. He at first thought that these bands were the edges of an infinity of laminæ of different reflective, and consequently refractive powers; but having observed that the same bands which reflected most light in one position reflected least light in another, he was driven to the conclusion that *all the bands were the edges of veins or laminæ whose visible terminations were inclined at different angles not exceeding a few seconds to the general surface.* Had this surface been an original face of the crystal, there would have been nothing surprising in its structure; but being a surface ground and polished by art, the phenomenon which it presents is one extremely interesting. The two or three images, therefore, which this lens gave as a microscope were produced by the convergency of the rays to different foci by the differently inclined faces of the laminæ.[1]

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[1] Mr Pritchard informs us (see *Edinburgh Journal of Science*, No. 1, new series, p. 149, July 1829), that Messrs Rundell and Bridge, at the time when Mr Pritchard began his experiments, had many Dutch diamond-cutters at work, and that the foreman, Mr Levi, with all his men, assured him *that it was impossible* to work diamonds into spherical lenses. The same opinion, he adds, was also expressed by several others, who were considered of standard authority in such matters. When Mr Pritchard had, contrary to the expectation of many, succeeded in finishing his first lens, it was examined by Mr Levi, who expressed great astonishment at it, and added, that he was not acquainted with any means by which that figure could have been effected.

[1] *Edinburgh Phil. Trans.*, vol. viii., p. 157, 1817. See also *Geological Transactions*, new series, vol. iii., p. 455; and *London and Edinburgh Philosophical Magazine*, vol. vii., p. 245.

Similar lines on the cut faces of diamonds have been observed by MM. Trecourt and Oberhauser, who consider them as minute prismatic canals or interstices left during crystallization, and who suppose that they injure the image in consequence of ground-off particles lodging themselves in the orifices of the canals, and which afterwards come out and destroy the polish by the scratches they produce. This explanation is in no way applicable to the phenomenon we have described.

These observations will, we trust, induce opticians to use the diamond more frequently than they were disposed to do when they believed that its imperfections arose from its doubly-refracting structure. In a small lens the doubly-refracting structure, when it does exist, is too small to produce any bad effect; and it is not difficult to discover any defect that may exist in the surface such as we have described above.

As the expense of the diamond, and the labour of working it, are very great, about fifty or sixty hours being necessary to complete a diamond lens with double convexity, it is of the greatest consequence to ascertain beforehand if the substance of the diamond is homogeneous; that is, free from difference of density or double refraction, and if it does not contain any small cavities. The best way is to examine the stone, by cutting two flat faces upon it, unless it is a *laske* or table diamond, which always has two flat faces; but this labour may often be avoided by examining it when plunged or held in a glass trough containing *oil of cassia*, the fluid which approaches nearest to it in refractive power. This will diminish all the refractions at the irregular surface of the diamond to such a degree as to make any internal imperfections as easily seen as if its substance were plate-glass.

By comparing the indices of refraction of diamond and glass, it may be easily shown that the same magnifying power may be obtained with a *diamond* lens having its curvature with a radius of 8, as with a *glass* lens the radius of whose curvature is 3; and as the spherical aberration increases with the depth of curvature or the thickness of the lens, a lens of diamond will bear a much larger aperture than one of glass before indistinctness of vision is produced. Mr Pritchard has given a very useful ocular representation of the relative value of a diamond and a glass lens. In the annexed figure G is the section of a semi-lens of glass, and D the section of one of diamond. so placed that their principal focus F shall be at the same point. In the diamond semi-lens the marginal rays will intersect the axis at d, and in the glass semi-lens at g; the longitudinal aberration being dF in the *diamond*, and gF in the *glass* lens.

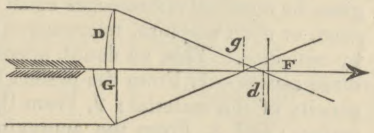

Fig. 10.

In order to obtain a numerical measure of these aberrations, Mr Pritchard computed them from the formula, and found that of the diamond lens to be $\frac{3}{7}$ths of its own thickness, that of the glass lens being $\frac{7}{6}$ths of its thickness; and by taking the thickness of the diamond lens to be 255, while that of the glass is 758, he obtained $\frac{3}{7}$ths of $255 = 108$, and $\frac{7}{6}$ths of $758 = 884$, and hence it follows that *the actual aberration of a* DIAMOND *lens is only about one-ninth of the aberration of a* GLASS *lens* of the same power and aperture.

If we suppose the diamond lens to be ground on the same tool with the glass lens, so as to have the same curvature, the same thickness, and the same diameter, the longitudinal aberration of the diamond will be to that of the glass lens as 43 is to 117, or nearly one-third of it; and if we suppose the focal length of both to be $\frac{1}{80}$th of an inch, the magnifying power of the diamond lens will be 2133, while that of the glass one will be only 800.[1] In order that a lens of glass may have the same magnifying power as that of the diamond above mentioned, its focal distance would require to be only the 200th part of an inch.

The durability of the diamond lens is also another valuable property, which allows it to be burnished into a disc of metal, and taken out and cleaned without any danger of being scratched. In treating of microscopic doublets and achromatic microscopes, we shall have occasion to recur again to the diamond lens. Some writers have objected to the use of diamonds because they are too costly. For ordinary microscopes, intended solely to amuse or to instruct, they have not been recommended; but if we wish to make great discoveries, to unfold the secrets yet hid in the cells of plants and animals, we must not grudge a diamond to reveal them. If Sir James South, Mr Cooper, and others, have given two or three thousand pounds for a refracting telescope, and if Lord Rosse expended L.15,000 on a reflecting one, why may not other philosophers open their purse, if they have one, and other noblemen sacrifice some of their household jewels, to resolve the microscopic structures of the lower world, to unravel mysteries most interesting to man, and secrets which the Almighty must have intended that we should know.

Sapphire Lenses.

Sapphire lenses.

The ruby and the sapphire are the same substance, differing only in colour. Mr Pritchard has, with his usual success, executed many lenses of sapphire, which, though inferior to those of diamond, are vastly superior to the best executed lenses of glass. When a double convex lens of sapphire and one of plate-glass are ground to the same focus, so as to have the same aperture and magnifying power, their relative curvatures are as 5 to 3, and their thicknesses as shown in the annexed figure, where A is the section of a semi-lens of sapphire, whose focus is at F, and B a section of a semi-lens of glass, having its focus at the same point. This figure points out in the clearest manner another advantage of using the precious stones in place of glass. In small lenses of glass, the thickness of the glass is such that there is no room between its anterior surface and the object for the admission of instruments for dissection, and not even for the thinnest plate of glass, so that it is impossible to use glass lenses of small foci in viewing objects placed in glass sliders. If the preceding figure represents lenses with a focus of $\frac{1}{30}$th of an inch, the distance of the glass lens B from F will be little more than $\frac{1}{60}$th of an inch, which is less than the thinnest glass.

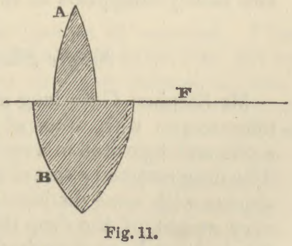

Fig. 11.

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[1] See *Phil. Trans.*, 1841, p. 41, for a drawing of the phenomenon.

[1] See the last column of the table in page 771, col. 2.

In using the *sapphire* and *ruby*, or any precious stone which refracts doubly, such as *zircon*, *topaz*, &c., for lenses, we are exposed to a very serious defect, arising from the duplication of minute lines, in consequence of the double refraction of these crystals. In order to remedy this defect, the optician endeavours to cut the stone so that the axis of the lens may coincide with the axis of double refraction. This, however, is a difficult task; and, even if it were accomplished, we should not get rid entirely of the duplication of the images, as in all double convex lenses, as well as in plane convex lenses with the plane side turned to the object, the rays cannot pass through the lens in parallel directions, and therefore must suffer double refraction, however small. It may be reduced, however, to the smallest possible amount, and even to nothing; for pencils of rays diverging from a point in the axis, by making the lens plano-convex, and turning the plane side to the eye, as in the annexed figure, where rays issuing from F, and entering the eye parallel at E, must pass through the lens AB in parallel directions, suffering all their refraction at the first or curved surface of the lens. By adopting this form and position of the lens, we may, however, lose more than we gain; for the lens is placed in the position which gives a maximum spherical aberration. When the magnifying power is not very high, the residual double refraction is not injurious; and in proof of this we may state, that we have in our possession a double convex lens of sapphire, executed by Mr Pritchard, which exhibits minute objects with the greatest beauty and precision. The only way, therefore, is to employ precious stones, such as the *diamond*, the *garnet*, and the *spinelle ruby*, which have no double refraction.

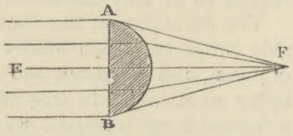

Fig. 12.

Garnet and Spinelle Ruby Lenses.

Garnet and spinelle ruby lenses.

The garnet is superior in its structure to the spinelle ruby, and the best and purest which we have seen is that which is brought from Greenland, and has a slight tinge of purple. We have used lenses made of this substance by Mr Hill, Mr Adie, Mr Blackie, and Mr Veitch, all of which exhibit minute objects with admirable accuracy and precision; and we can state with confidence, that we have never experienced the slightest inconvenience from the colour of the garnet, which diminishes with its thickness, and therefore nearly disappears in very minute lenses. (See p. 774.)

Single Fluid Microscopes.

Single fluid microscopes.

Mr Stephen Gray long ago proposed to construct single microscopes with drops of water, which he lifted up with a pin, and deposited in a small hole made in a piece of brass. The drop retained a sort of imperfect sphericity, and showed objects with some distinctness; but it is obvious that the very weight of the drop destroyed its spherical form, even if it had not been disturbed by minute irregularities on the circumference of the aperture in which it was placed.

Sir David Brewster long ago constructed fluid lenses in a different manner, so as to avoid the irregularities above mentioned. He placed minute drops of very pure turpentine varnish, and other viscid fluids, on plates of thin and parallel glass. By this means he formed plano-convex lenses of any focal length; and by dropping the varnish on both sides, he formed double convex lenses, with their convexities in any required proportion. By freeing the glass carefully from all grease with a solution of soda, the margin of these lenses was beautifully circular; and the only effect of gravity, which diminishes with the viscidity of the fluid and with the smallness of the drop, is to elongate the lower lens and flatten the upper one. These lenses were found to answer well as the object-glasses of compound microscopes.

Method of making them.

After experiencing the extreme difficulty of obtaining precious stones free of double refraction or difference of density, and from little cavities and imperfections, as well as the difficulty of giving their surfaces a perfect polish and a correct figure, Sir David Brewster made an extended series of experiments on the formation of minute fluid lenses, which should equal in power and distinctness those made of precious stones. The primary difficulty which was encountered in this attempt was that of depositing a sufficiently minute drop of fluid upon a surface of glass. This arose from two causes: from the difficulty of taking up on the slenderest fibre a minute globule of a fluid of any moderate tenacity, and the still greater difficulty of overcoming its adhesion to the fibre, and laying a portion of it on glass. The first of these difficulties he overcame by a suitable mixture of two fluids, and the second by a mechanical process. Having thus succeeded in obtaining lenses too small to be recognised distinctly by the eye, he next endeavoured to make their figure approximate to the hyperbolic form when the lenses were not of the smallest size; and the results which he obtained were far beyond his expectation. Some of these lenses preserved their perfection for more than a year, and if protected from dust might have been kept much longer. If fluids could be obtained of a high refractive power, and not of a volatile nature, microscopes of extreme perfection might thus be readily constructed.

In order to deposit upon glass a very minute portion of fluid, Sir D. Brewster employed a fibre of spun glass. When slightly dipped into the fluid, the portion which adhered to its extremity, in place of remaining in the form of a small globule, ran along the fibre, so that it could not be laid upon the glass. Upon holding the fibre vertically, and repeatedly knocking the hand which held it upon the thigh, the fluid was gradually made to accumulate at the end of the fibre, so that it could be made to touch the glass surface, and leave a small portion in the form of a plano-convex lens.

The desired result was produced more effectually by fixing the upper end of the fibre in the stand of a microscope, so as to suspend it vertically above the glass plate. By turning the milled head, and making the drop at the end of the fibre descend, or the glass ascend, till they were nearly in contact, it was easy, by a rapid separation of the two after contact, to leave the smallest portion upon the glass.

It is obvious that this operation could not be performed, if the fluid had much tenacity, like Canada balsam in its usual condition. Sir David Brewster therefore tried to obtain a fluid of the proper tenacity, and found that a mixture of castor oil and Canada balsam answered the purpose when carefully incorporated.

With this fluid, and with others, suspended, as shown in fig. 13, from plates of thin parallel glass, he obtained microscopes equal to the glass, or even sapphire, microscopes made by opticians. This, no doubt, arises from three causes,—1. From the perfect homogeneity of the material; 2. From the perfect polish of the surface; and, 3. From the approximation of the figure of the lens to the hyperbolic curve. The form of the curve will obviously vary with the size of the drop and the tenacity of the fluid.[1]

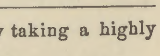

Fig. 13.

The curvature of the lens may be changed by suspending the drop from convex or concave surfaces, as in figures 14 and 15. With the view of altering the curvature of the fluid lenses, immiscible fluids were used, such as *treacle*

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[1] The form of the lens may be ascertained by taking a highly magnified image of it.

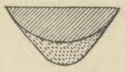
Fig. 14.

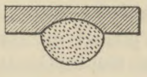
Fig. 15.

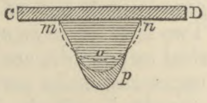

Fig. 16.

or *honey*, and *castor oil*. The dotted line *mon* (fig. 16) shows the original *castor oil* lens, and the horizontally lined lens the form into which it is pulled by the weight of the *treacle* or *honey* lens *p*. The effect of this combination was very good.

In place of the plate CD (fig. 16), we may use a convex

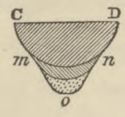

Fig. 17.

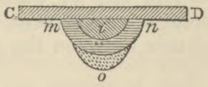

Fig. 18.

lens as in fig. 17, where *mn* is the *castor oil*, and *o* the *treacle* meniscus.

An achromatic combination may be made as in fig. 18, CD being the glass plate, *i* a plano-convex lens, *mn* a concave lens of a highly refractive and dispersive oil, and *o* a meniscus of treacle or Canada balsam softened.

We may pull down a fluid lens *abc* (fig. 19) into a hyperboloidal form by the weight of a lens of glass *mn*. In an experiment thus made there was not a trace of spherical aberration. There is no occasion in this case of a small

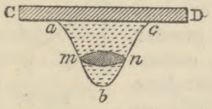

Fig. 19.

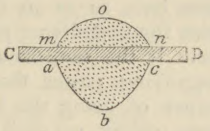

Fig. 20.

aperture, as the treacle lens *abc* excludes all lateral light. The effect of suspending the lens of a minnow at *mn* was good.

If the fluid lens is too hyperbolic, it may be corrected by a flattened lens *mon* (fig. 20) placed above the glass plate CD.

Single Catadioptric Microscope.

Single catadioptric microscope.

A single lens, by which light is both refracted and reflected, seems at first sight to be something paradoxical. Such a lens, however, which was proposed and used by Sir David Brewster, is shown in the annexed figure, where ABC is a hemispherical plano-convex lens, which, if we use it in the common way, will have a certain magnifying power; but if we use it as shown in the figure, it acts as a double convex lens of the same radius, and has consequently twice the magnifying power. Bisect the semicircle BAC in A, and join AB, AC. If we now place an object at *mn*, and look into the lens BA at F, we shall see by reflection from the surface BC the object *mn*, with the same distinctness, and under the same angle, as if we had placed the two lenses A*a*B*d*, A*a*C*d*, with their plane sides AB, AC together. Since the light is incident on the reflecting surface BDC at an angle of 45° and upwards, not a ray of it will be transmitted, as it suffers total reflection. The lens thus used, composed in reality of two plano-convex ones, A*a*C*d*, A*a*B*d*, has less spherical aberration than when used as a whole, ABC, and there is obviously no error from imperfect centering. This lens may be used as the object-glass of a compound microscope; and it will be seen in another section that it possesses other advantages than those which have been mentioned.

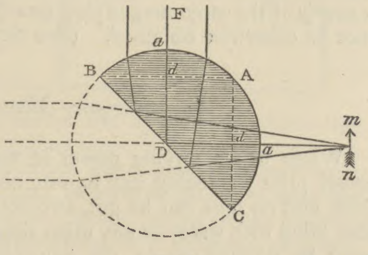

Fig. 21.

The Grooved Sphere.

Grooved sphere.

This lens derives its name from its having a deep groove cut round it in the plane of a great circle perpendicular to the axis of vision. Sir David Brewster was led to its construction by the doublet of Dr Wollaston, which will be described in another section. It consists of a spherical lens or sphere, with a deep concave groove cut round it, so as to cut off the marginal pencils, and thus give a wider field and a more perfect image. It is represented in the annexed figure, where ABDC is a sphere of glass, having the unshaded parts below AC and above BD cut away, in order to prevent rays that fall very obliquely from reaching the eye. The central thickness of the lens may be made so small as to render the spherical and even the chromatic abberration almost insensible. As all the pencils pass through the centre, every part of the image will be equally distinct; a property possessed by no other lens.

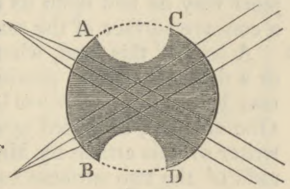

Fig. 22.

This lens, as fitted up by Mr Blackie for the inventor, is shown in the annexed figure; AB being a representation of it when closed, and ABC when open; the lens at A resembling a bird's eye.

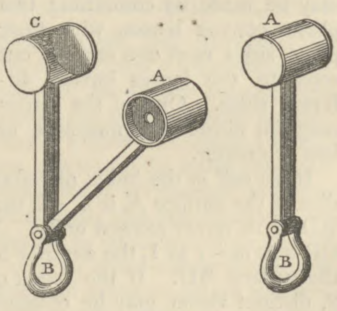

Fig. 23.

Mr Coddington,[1] who entertains a high opinion of the value of this lens, observes:—"Besides all this, another advantage appears in practice to attend this construction, which I did not anticipate, and for which I cannot now at all account. I have stated that when a pencil of rays is admitted into the eye, which, having passed without deviation through a lens, is bent by the eye, the vision is never free from the coloured fringes produced by eccentrical dispersion. Now with the sphere I certainly do not perceive this defect; and I therefore conceive that if it were possible to make spherical glass on a very minute scale, it would be *the most perfect simple microscope*, except, perhaps, Dr Wollaston's doublet,[2] than which I can hardly imagine anything more excellent, as far as its use extends; its only defects being the very small field of view, and the impracticability of applying it, except to transparent objects seen by transmitted light. Now, the sphere has this advantage, that whereas it makes *a very good simple microscope, it is more peculiarly* fitted for the object-glass of a compound instrument, since it gives a perfectly distinct image of any required extent, and that, when combined with a proper eye-piece, it may without difficulty be employed for opaque objects." We do not rightly apprehend the exact import of these observations. Mr Coddington distinctly asserts that the grooved sphere is the most perfect simple microscope, or the most perfect microscope with one lens; and yet he says in the next paragraph that it is only "a very good simple microscope," being "more peculiarly fitted for a compound instrument."[1]

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[1] *Phil. Trans.*, 1830, part i., pp. 69–84.

[2] This exception was needless, as the doublet is not a simple microscope, having two lenses placed at a distance.

With regard to the difficulty of making it on a small scale, it is by no means great; for if we can grind and polish its two surfaces, we may readily excavate it round its margin. We have now before us a grooved sphere of garnet $\frac{1}{24}$th of an inch radius, executed by Mr Blackie: The focus is almost close to the lens, which in many kinds of observation is a great advantage, and its performance is remarkably fine.

It will be seen in our article on OPTICS, that when the refractive index of a sphere exceeds 2·000, its focus falls within the sphere. Hence a grooved sphere made of diamond is useless. When made with garnet it is invaluable; and its focus is just thrown so near its surface, that the objects may be laid upon its surface, or pressed against it by a concave surface of the same radius.

Concentric lenses.

A lens of this kind, whether the surfaces have the same or a different radius, provided they have the same centre, may be called a *concentric* lens, and has valuable properties. One of these, executed upwards of thirty years ago for the writer of this article by Mr Blackie of Edinburgh, has the radii of the two surfaces so adjusted that its anterior focus is on the least convex surface. It is shown in the annexed figure, where C is the common centre of the two surfaces A and BD; the groove round C being cut to the requisite depth.

An equivalent concentric lens may be made by combining two plano-convex lenses, with their plane sides next one another cut separate, the lenses having different sides. One of the lenses may be either a hemisphere or less or greater.

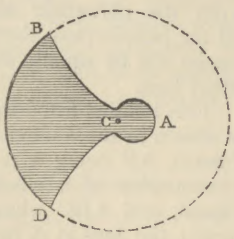

Fig. 24.

If we call m the index of refraction, then if AC, the radius of the surface A, is $m-1$, the radius CB of the surface BD must never exceed unity. When the ratio of CA to CB is as $m-1$ to 1, the anterior focus of the lens will be on the surface BD. If the index of refraction m is beneath 2, distinct vision may be obtained by looking into either surface. When the index is 2, the only concentric lens that can be made consists of two hemispheres united, or a sphere. When the index is above 2, distinct vision can be obtained only by looking into, or placing next the eye, the least convex surface.

The Fluid Grooved Sphere.

Fluid grooved sphere.

In order to construct a grooved sphere with fluids, Sir David Brewster adopted the arrangement shown in the annexed figure, where AB is a piece of plate-glass of a circular form, having a groove cut out of its circumference. Two fluid lenses m, n, as nearly hemispherical as possible, are then placed on its upper and under surface by the methods already described. The aberration both from form and colour will be reduced by the groove, as well as by the form of the under lens.

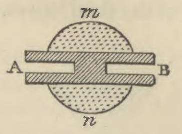

Fig. 25.

The same effect may be produced by substituting for the piece of glass AB two thin plates of parallel glass, or thin laminæ of split topaz *ab*, *cd* (fig. 26), separated by a circular plate of metal, with a proper aperture, the three plates being cemented into one by Canada balsam, or any homogeneous cement which may fill the aperture between the glass-plates.

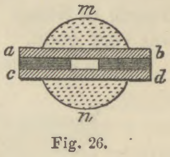

Fig. 26.

Compound Single Microscopes.

Compound single microscope.

We may give this name to any combination of lenses which acts solely as a single microscope. When we possess single lenses with little magnifying power, we may double or quadruple their power by cutting them into halves, quarters, or more numerous sections, and placing them transversely, as in the annexed figure. In this figure is represented a combination of two semi-lenses ABC, DEF cut from the same lens, so as to form a lens having twice the magnifying power of the original one. If the semi-lens ABC has a greater magnifying power than DEF, in consequence of being the half of another lens more convex, we shall have *three* different magnifying powers in the same combination,—the *highest* power in the portion EB, a *lower* power through the portions m, o, and a still lower power through the portions n, p.

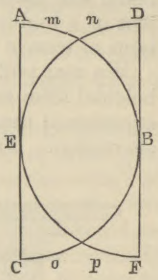

Fig. 27.

A combination of quarters of lenses, having the same properties as those above described, is shown in the annexed figure. The quarter lenses may be combined as in the upper or lower half of the preceding figure, and several of such combinations may be united for optical purposes, and made achromatic by the usual methods.

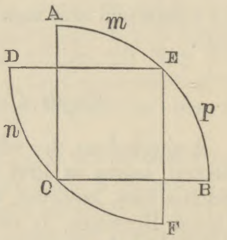

Fig. 28.

The preceding method of combining divided lenses enables us to make two or more lenses, or microscopes, or telescopes *exactly* of the same magnifying power; an effect which cannot be otherwise obtained. (See STEREOSCOPE.)

An Extempore Microscope.

Extempore microscope

When a magnifying power is wanted for reading any small print or seeing any minute object, and no lens can be got, two bottles filled with water or any other fluid may be crossed, as in the annexed figure, and the object viewed through the middle portion ABCD. Two very small bottles, or two test tubes, crossed in the same manner, will have a considerable magnifying power.

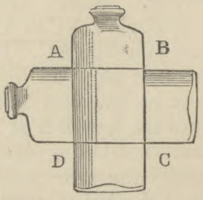

Fig. 29.

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[1] This lens, which has very incorrectly been called the "Coddington lens," was not invented by Mr Coddington, nor was its invention ever claimed by him. It was invented by Sir David Brewster, and constructed in Edinburgh of glass and garnet long before 1820, and an account of it was published in the *Edinburgh Philosophical Journal*, April–July 1820. Mr Coddington takes no notice of it in his *Treatise on Optics*, published in 1823, but he mentions it without any name in his Treatise *On the Reflection and Refraction of Light*, published in 1829. Mr Coddington, we have reason to believe, got a grooved sphere made by Mr Carey or some other London optician, who, supposing it to be new, gave it a name to which it was not entitled. Had Mr Coddington been alive, he would have been one of the first to give it its true name.

Crystalline Lenses of Small Fishes.

The crystalline lens of minnows and small fishes may be taken out of the eye in a state of such perfection, that when used as single microscopes, they give a very perfect image of minute objects. In such lenses, which have an increasing density towards their centre, the spherical aberration is almost wholly corrected. Great care, however, must be taken to make the axis of the lens the axis of vision, to prevent its form from being injured by pressure against the aperture which holds it. The best way is to make a ring at the end of a piece of wire, having its diameter a little greater than that of the lens. A ring of viscid fluid is then made to line the ring of wire, and the lens is suspended in the ring of fluid, some of the fluid encroaching upon its anterior or posterior surface.

Magnifying Power of Single Microscopes.

Magnifying power.

Having thus described the various kinds of single microscopes, we shall now consider the subject of their magnifying power. When an eye in the prime of life, and neither long nor short sighted, views the minutest object which it can recognise, it will generally place it at the distance of about five inches. When the same object is viewed through a single microscope, the distance at which it is seen is equal to the focal length of the lens; and as the apparent magnitude of objects is inversely as the distances at which they are seen, we have only to divide the distance, five inches, by the focal length of the lens, in order to know its magnifying power, or the apparent magnitude of objects when seen through the lens.

The following table shows the magnifying power of lenses of all focal lengths, from 5 inches up to the 100th of an inch, and is applicable to all lenses, of whatever substance they are made :—

Focal Length.	Magnifying Power.	Focal Length.	Magnifying Power.
Inches.		Inches.	
5	1	$\frac{1}{17}$	85
2	$2\frac{1}{2}$	$\frac{1}{18}$	90
$1\frac{3}{4}$	$2\frac{5}{6}$	$\frac{1}{19}$	95
$1\frac{1}{2}$	$3\frac{1}{3}$	$\frac{1}{20}$	100
$1\frac{1}{4}$	4	$\frac{1}{25}$	125
1	5	$\frac{1}{30}$	150
$\frac{3}{4}$	$6\frac{2}{3}$	$\frac{1}{35}$	175
$\frac{1}{2}$	10	$\frac{1}{40}$	200
$\frac{1}{3}$	15	$\frac{1}{45}$	225
$\frac{1}{4}$	20	$\frac{1}{50}$	250
$\frac{1}{5}$	25	$\frac{1}{55}$	275
$\frac{1}{6}$	30	$\frac{1}{60}$	300
$\frac{1}{7}$	35	$\frac{1}{65}$	325
$\frac{1}{8}$	40	$\frac{1}{70}$	350
$\frac{1}{9}$	45	$\frac{1}{75}$	375
$\frac{1}{10}$	50	$\frac{1}{80}$	400
$\frac{1}{11}$	55	$\frac{1}{85}$	425
$\frac{1}{12}$	60	$\frac{1}{90}$	450
$\frac{1}{13}$	65	$\frac{1}{95}$	475
$\frac{1}{14}$	70	$\frac{1}{100}$	500
$\frac{1}{15}$	75		
$\frac{1}{16}$	80		

We have already mentioned the advantages which the precious stones have over glass ones, in having a much less spherical aberration. In order that a glass lens may have the least spherical aberration, its radii of curvature must be as one to six, the flattest side being turned to the object; but this is not the case with bodies of a different refractive power. Mr Coddington, in his *Treatise on the Reflection and Refraction of Light*,[1] has computed the ratio of the curves when the aberration is a minimum for various indices of refraction from 1·5 up to 2·0, and the amount of the aberration itself in parts of the thickness of the lens. This table is very important in a practical point of view, as will be seen from the observations which follow it.

Spherical aberration.

Table showing the Spherical Aberration of Lenses of Glass and the Precious Stones, and the proper proportion of their Radii when the Aberration is a Minimum :—

Substances.	Index of Refraction.	Ratio of the Radii of a Lens of Minimum Aberration.	Longitudinal Aberration, the thickness being 10.
Fluor spar……………… Cryolite ………………	1·4	1 to 3·66	10·96
Glass plate……………… Oil of almonds ………… Castor oil……………… Honey………………	1·5	1 to 6	10·71
Flint glass……………… Quartz……………… Topaz……………… Oil of cassia………………	1·6	1 to 14	9·33
Glass, lead 1, flint 2…… Sulphuret of carbon ……	1·7	1 to −93	6·66
Sapphire……………… Ruby……………… Spinelle ruby……………… Garnet……………… Glass, lead 2, flint 1½……	1·8	1 to −12	3·57
Sulphate of lead……… Glass, lead 2½, flint 1……	1·9	1 to −7	1·66
Zircon……………… Calomel……………… Sulphur ……………… Phosphorus ……………… Glass, lead 3, flint 1……	2·0	1 to −5	0·62

It appears from the preceding table, that when the refractive index is between 1·4 and 1·6 and a little more, but less than 1·7, the second surface of the double convex lens must be *convex*, in order to have the least spherical aberration; but that when the index is a very little above 1·6, the second surface must be *plane*, and when the index is nearer 1·7 than 1·6 the second surface must be *concave*, in order to make the aberration a minimum, and this concavity, in the case of zircon and sulphur, is so much as −5, so that in diamond it must be nearly −3; so that we must sacrifice a great deal of magnifying power in order to obtain this advantage in diamond; but the sacrifice will be well bestowed, for such a lens will be almost wholly free of spherical aberration.

Notwithstanding the difficulty of the task, we would earnestly direct the attention of artists to the subject of grinding plano-convex lenses of a hyperbolic form for single microscopes. The smallness of the lens must increase the difficulty; but in this case the effect may be accidentally obtained, as it is often done in giving a parabolic and an elliptical form to specula. Mr Potter has given, and put to the test of experiment, a method of obtaining any curve derived from revolution, by giving a particular form to the grinding and polishing tools. (*Edin. Jour. of Science*, new series, No. 12.)

CHAPTER II.

DESCRIPTION OF MICROSCOPIC DOUBLETS AND TRIPLETS.

Doublets and triplets.

Under this chapter we propose to describe all combinations of lenses in which two or more are placed in contact, or at such a distance that no image is formed between them.

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[1] Page 111, Cambridge, 1829.

Wollaston's Periscopic Doublet.

Periscopic doublet.

The earliest proposal of a doublet lens was that which Dr Wollaston made (*Phil. Trans.* 1812, p. 375), under the name of a periscopic microscope. The following is his own description of it:—"The great desideratum," says he, "in employing high magnifiers, is sufficiency of light; and it is accordingly expedient to make the aperture of the little lens as large as is consistent with distinct vision. But if the object to be viewed is of such magnitude as to appear under an angle of several degrees on each side of the centre, the requisite distinctness cannot be given to the whole surface by a common lens, in consequence of the confusion occasioned by oblique incidence of the lateral rays, excepting by means of a very small aperture, and proportionable diminution of light. In order to remedy this inconvenience, I conceived that the perforated metal which limits the aperture of the lens might be placed with advantage in its centre; and accordingly I procured two plano-convex lenses ground to the same radius, and applying their plane surface on opposite sides of the same aperture, in a thin piece of metal (as is represented by a section, fig. 30), produced the desired effect, having virtually a double convex lens, so contrived that the passage of oblique pencils was at right angles with its surface, as well as the central pencil. With a lens so constructed, the perforation that appeared to give the most perfect distinctness was about *one-fifth* part of the focal length in diameter; and when such an aperture is well centered, the visible field is at least as much as 20° in diameter. It is true, that a portion of light is lost by doubling the number of surfaces; but this is more than compensated by the greater aperture which, under these circumstances, is compatible with distinct vision."

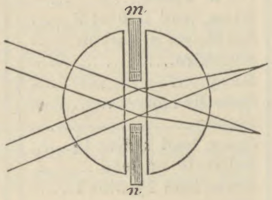

Fig. 30.

PERISCOPIC SPHERE.

Periscopic sphere.

In the preceding passage Dr Wollaston describes only a double convex periscopic microscope, consisting of two plano-convex lenses; but he does not take the case where these two lenses are hemispheres, and consequently where the doubly convex one which they form is a sphere. When the lenses are not hemispheres, the pencils are not centrical, and the rays from different parts of the object do not each suffer the same species of refraction as they do when passing through a sphere, so that every part of the field is not equally distinct. It is obvious also that Dr Wollaston did not think of filling up the central aperture with a fluid of the same refractive power as the lens, in order to remove the loss of light from the double number of surfaces, which he mentions as a defect in his microscope.

The construction of a periscopic sphere proposed by Sir David Brewster combines these two properties. The lenses, whether they are hemispherical or not, must be so placed that their convex surfaces form part of the same sphere, as shown in the annexed figures.

In fig. 31 the plano-convex lenses AB, CD may be cemented to a piece of plate-glass *mn*, of such a thickness in one direction as to complete the sphere, and of such a diameter in the direction *mn* as to form a suitable contraction of the aperture.

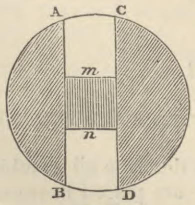

Fig. 31.

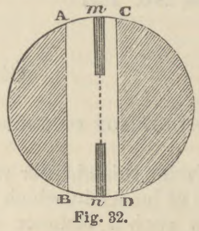

Fig. 32.

In fig. 32 the space between the two unequal lenses may be filled up, as in the figure, by two pieces of plate-glass A*mn*B, C*mn*D, between which is a plate of brass, or of thin black paper, containing a suitable aperture in the centre of the lenses. Here there are *six* surfaces within the sphere; but by uniting them with a proper cement, the whole becomes a single sphere, in which there is no perceptible loss of light.

In fig. 33 lenses of unequal size and thickness are combined either with a plate of glass or a fluid between them of the same refractive power as the glass, and the apertures may be placed on the plane surfaces AB, CD.

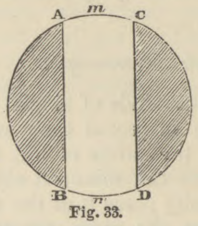

Fig. 33.

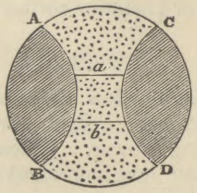

Fig. 34.

In fig. 34 two convex lenses may be combined into a sphere, the intermediate portion being filled up with a fluid of the same refractive power. This may be readily done by cementing each lens on the end of a brass or glass tube *ab*, and introducing the fluid by an aperture.

In uniting these lenses, it is obviously necessary that the convex outer surfaces should be exactly of the same curvature and of the same kind of glass. The best way of effecting this is to grind a thick lens ABC, either greater or less than a hemisphere, and then to bisect it at AD, and out of the portions ADB, ADC to form two plano-convex lenses ABE, ACF, or two double convex lenses AEBG, AFCH. The outer surfaces of these two lenses will belong accurately to the same sphere. The perfect similarity of the inner surfaces is of less consequence, as all refraction by them is wholly removed by the cement if it has the same refractive power.

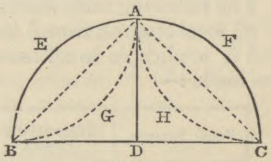

Fig. 35.

By these different steps Sir David Brewster was led to the idea of the grooved sphere, or the lens already described under the head of single microscopes, in which the aperture is contracted by excavating the sphere all round in one of its great circles.

PERISCOPIC ACHROMATIC SPHERES.

Periscopic achromatic sphere.

If, in the construction shown in fig. 36, in place of making the fluid *op* of the same refractive and dispersive power as the two lenses, we make it such as to correct the colour of these lenses, we shall obtain an achromatic sphere, as proposed by Sir David Brewster; and the compound lens may be still farther improved as a microscope by attaching, either by cement or not, to the back of the first lens AB a convex speculum of silver or steel for illuminating the object, the contracted aperture being the hole in the centre of the speculum. The concave fluid lens is shown at *op*; and such a curvature must be given to the convex reflector *mn* that it may reflect parallel or diverging rays upon the object.[1]

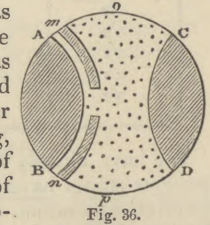

Fig. 36.

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[1] *Edinburgh Philosophical Journal*, 1820, vol. iii., pp. 74–77; and Pritchard's *Treatise on Optical Instruments*, in the Library of Useful Knowledge, p. 41, § 66.

Mr Coddington[1] thus treats of the preceding contrivance:—"An achromatic sphere may be constructed by interposing between two crossed lenses (double convex ones), in opposite positions, a concave lens of a medium more highly dispersive than that of the lenses, adjusting the curvatures so that the outer surfaces of the crossed lenses shall be portions of the same sphere, and that the interior surfaces shall exactly fit into each other.

"In such a system, we may consider the effect to be the same as that of an entire sphere of the same medium as the two lenses diminished by that of a concave lens having for its refractive ratio that which exists between the two media in question.

"Thus, if μ_1 be the ordinary index of refraction for the convex lenses, μ_2 for the concave one, $\pi : 1$ the ratio of the dispersive powers, r the radius of the sphere s, σ those of the internal surfaces, we must have

$$\left(\frac{\mu_2}{\mu_1}-1\right)\left(\frac{1}{s}+\frac{1}{\sigma}\right) : 2\frac{\mu_1-1}{\mu_1}\frac{1}{r}=\pi : 1;$$

whence it follows that $\frac{1}{s}+\frac{1}{\sigma}=2\pi.\frac{\mu_1-1}{\mu_2-\mu_1}\frac{1}{r}$.

For example, let $\mu_1=1,5$; $\mu_2=1,65$; $\pi={}_11,25$.

$$\text{Then, } \frac{1}{s}+\frac{1}{\sigma}=\frac{1}{4}\cdot\frac{,5}{{}_1,5}\frac{1}{r}=\frac{1}{1,2r}.$$

If the first internal surface be plane, or $s=\infty$, we have in general $\sigma=\frac{1}{2\pi}\frac{\mu_2-\mu_1}{\mu_1-1}r$; or, in this particular example, $\sigma=1,2r$, or $\sigma : r=6 : 5$."

DOUBLET OF NO ABERRATION.

Herschel's doublets of small aberration.

So long ago as 1668, a doublet was described in the *Philosophical Transactions*, in which a large and flat field was obtained. This subject, however, was never investigated with care till Sir John Herschel took up the subject in 1821. The doublet, made of glass, which Sir John proposes for obtaining perfect distinctness in microscopical observations, is shown in the annexed figures 37, 38, the convex sides being turned to the eye when the doublet is used as a microscope, and to the sun when it is used as a burning-glass. The following are the radii and focal length of these lenses:—

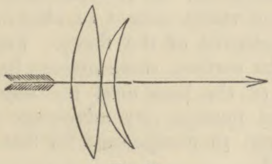

Fig. 37.

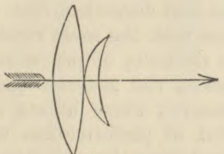

Fig. 38.

	Fig. 37.	Fig. 38
Focal length of the *first* lens	+10·000	+10·000
Radius of its first surface	+ 5·833	+ 5·833
Radius of its second surface	−35·000	−35·000
Focal length of the *second* lens	+17·829	+ 5·497
Radius of its first surface	+ 3·688	+ 2·954
Radius of its second surface	+ 6·291	+ 8·128
Focal length of the *combined* lenses	+ 6·407	+ 3·474

"Whether we ought or ought not," says Sir John, "to aim at the rigorous destruction of rays parallel to the axis, the use to which the lens is to be applied must decide. In a burning-glass it is of the highest importance. A slight consideration will suffice to show, that the difference of temperatures produced in the foci of a double convex lens of equal radii, and one of the same focal length, but of the best form, must be very considerable. In order to try whether even the latter might not be improved by the shortening of the focus, and the superior concentration of the exterior rays, by applying a correcting lens of one of the forms above calculated, in spite of the loss of heat in passing through a second glass, I procured two lenses to be figured to the radii assigned in the first column of the foregoing table. They were about three inches in aperture, and when combined as above described, the aberration was almost totally destroyed, and probably would have been so completely had the index of refraction proper to the glass been employed instead of that adopted in our calculation for brevity. Their combined effect as a burning-lens appeared to me decidedly superior to that of the first lens used alone, and there is therefore good reason to presume that the effect of the other construction, which, with the same loss of heat, affords a much greater contraction of the focus, would be still better; and I regret not having tried it in preference.

"In eye-glasses and magnifiers, if we would examine a minute object with much attention, as a small insect, or (when applied to astronomical purposes) if we would scrutinize the appearance of a planet, a lunar mountain, the nucleus of a comet, or a close double star, where extent of field is of less consequence than perfect distinctness in the central point, too much pains cannot be taken in destroying the central aberration." (*Phil. Trans.* 1821. p. 246-248.)

Mr Pritchard has executed some of these doublets for the object-glasses of compound microscopes, "for which," he says, "they answer remarkably well, but their angle of aperture is small compared with combinations of double achromatics." (*Microscopic Cabinet*, p. 163.)

Herschel's Periscopic Doublet.

Herschel's periscopic doublet.

We owe also to Sir John Herschel the construction of a periscopic doublet with a very large field of moderate distinctness. "In spectacles," says he, "reading-glasses, magnifiers of moderate power, and eye-glasses for certain astronomical purposes, the correction of the aberration in the centre of the field may be sacrificed with little inconvenience. By far the best periscopic combination I am acquainted with consists of a double convex lens of the best form, but placed in its worst position (radii as 6 to 1) for the lens next the eye, and a plane concave whose focal length is to that of the other as 2·6 to 1, or as 13 to 5, placed in contact with its flatter surface, and having its concavity towards the object, as in the annexed figure, for the farthest; yet for destroying the aberration of rays parallel to the axis nothing can be worse. In fact, our formula gives for the aberration in this construction 22·02, or about 22 times what the best single lens of equal power would give; yet on accidentally combining two such lenses in this manner, I was immediately struck with the remarkable extent of oblique vision, with the absence of fatigue, on reading some lines with a power much beyond that of the natural eye, and with the freedom from colour at the edges of the field, arising from *the opposition of the prismatic refractions* of the two solids; an advantage which a single meniscus does not possess." The focal length of the compound lens which Sir John tried was 1·84 of an inch. The field of tolerably distinct vision extended fully 40° from the axis, and the letters of a book might be read, and the forms of objects distinguished, with management, as far as the 75th degree. In using such a combination the lenses should be very thin, and the eye applied as close as possible.

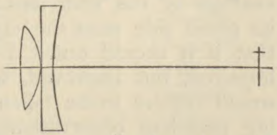

Fig. 39.

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[1] *Treatise on the Reflection and Refraction of Light*, p. 256.

Plano-Convex Doublet.

Plano-convex doublet.

A doublet of much simpler construction, and with its spherical aberration greatly diminished, has also been proposed by Sir John Herschel. It is represented in the annexed figure, and consists of two convex lenses of equal focal lengths, the convex sides being placed in contact, and the eye and object opposite the plane sides. In this case the aberration will be only 0·6028. But if we make the focal length of the first to that of the second as 1 to 2·3, the aberration will be reduced to 0·2481. In order to have an idea of the value of such a doublet, we shall give the series of aberrations for single lenses, as investigated by Sir John Herschel:—

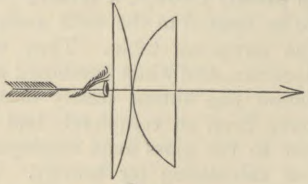

Fig. 40.

	Aberration.
Plano-convex, plane side first	4·2
Plano-convex, convex side first	10·81
Double convex	1·567
Best form of a single lens	1·00
Doublet of two equal plano-convex lenses	0·6028
Doublet of two plano-convex lenses with their focal lengths as 1 to 2·3	0·2481
Doublet of garnet, with suitable focal lengths	0·08

Garnet doublets.

As these calculations are made for glass, the advantage of such a doublet made of garnet or sapphire must be much greater. In a garnet the minimum aberration takes place when the form of the lens differs very little from that of plano-convex; and as it is then to that of glass as 35 to 107, the aberration will be only about 0·08, or next to imperceptible.

Wollaston's Doublet.

Wollaston's doublet.

The consideration of the Huygenian eye-piece for astronomical telescopes suggested to Dr Wollaston the probability that a similar combination should have a similar advantage, of correcting both achromatic and spherical aberrations, if employed in an opposite direction as a microscope.[1] With this view, he took two plano-convex lenses, the ratio of whose focal lengths was as 3 to 1, and he placed them as in the annexed figure, so that the distance of their plain surfaces was from $1\frac{4}{10}$ to $1\frac{5}{10}$ the focal length of the smallest. The plane sides of the lenses are towards the object. The advantage of the first lens having its plane side next the object is, as Dr Wollaston states, that if it should touch a fluid, the view is not only not impaired, but improved, whereas a double convex lens would require to be taken out and cleaned. The following excellent observations on this doublet are made by Pritchard:—

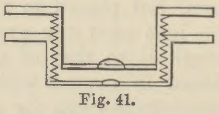

Fig. 41.

Pritchard's improvements.

"Having mounted some plano-convex lenses of the relative foci named by Dr Wollaston, in such a manner that the distances might be varied at pleasure, I was surprised to find that after the doublet was adjusted *by trial*, so as to obtain the maximum of distinctness, the distance between the lenses did not accord either with the rule given by Huygens, or that of Dr Wollaston. Supposing that I had not got the combination intended by Dr Wollaston, I procured several doublets made by different artists, and to my astonishment found they agreed with my own, and therefore presumed the Doctor was mistaken in the distance by the thickness of the lenses and the minuteness of the space between them. The distance which appeared to me essential to obtain the best effect, *is the difference of the focal length of the two lenses, making a proper allowance for their thickness.* The proportion of the foci of the two lenses may be varied *ad libitum.* All that is requisite in this respect is, that the difference must be greater than the thickness of the anterior lens, while it may be observed (in high powers), that the greater the difference between their two focal lengths the more space will be left in front; and as this is of great practical importance, they should never be less than as 1 to 3. I have made some very good ones, differing as much as 1 to 6. . . . . The following details are necessary to insure their goodness:—

"*First,* The convex surface of each lens must be *truly spherical.* If this is not obtained, it will be in vain to procure a good doublet, however beautifully the lenses may be polished or accurately adjusted. From this circumstance I have found globules perform very well, providing they are free from air-bubbles, which, however, is rarely the case. It should be observed, that a slight scratch on their surface is trifling compared to air-bubbles; for the latter not only stop the light, but, by the reflection around the edges of each bubble, produce considerable fog or glare. *Second,* The distance between the lenses is the next point of importance; its adjustment is best accomplished by trial, mounting the lenses in such a manner that their distance can be varied at pleasure, and capable of being turned round, so as to adjust the centering. When this is obtained, they should be fixed so that their distance and position cannot be altered. This it is necessary to regard, as I have sometimes spent whole days in re-adjusting a doublet that had been separated to examine the lenses singly. *Third,* The stop or diaphragm, for limiting the aperture in these combinations, should be placed immediately behind the anterior lens. From the difference of the situation of the stop in the various doublets I have examined, it will appear that their makers did not know that the field of view depended upon the plane of the stop. I have found, that when the stop is situated *close* behind the anterior lens, no other is required, and the field is enlarged without sensibly augmenting the aberration. On this account the lenses of the finest doublet, when used singly with the same aperture as combined, has so much aberration and distortion that distinct vision cannot be obtained, even with the most rigid adjustment of the focus. From the difficulty of procuring a flat surface, some makers have worked the anterior surface of the lens next the object concave: these lenses do not possess any advantage in point of performance, not even to compensate for loss of power from the negative side."

Blaikie's doublet.

Mr Pritchard remarks, that when the lens next the object is a jewel, the performance of the doublet is improved; but that he has not observed any advantage when both lenses are gems. This must be a mistake; for lenses of any gem, that are superior to glass ones when acting singly, must, if suitably combined, be superior also when united. In proof of this, we have a garnet doublet before us, executed by Mr Blaikie, the performance of which is quite remarkable. The lenses are made of Elie garnets, and their convex sides are placed towards each other. The radius of the smallest lens near the object is $\frac{1}{70}$th of an inch, and that of the other $\frac{1}{20}$th of an inch. Its magnifying power is very high, exceeding greatly that of the semi-jewel doublet made by Mr Pritchard, with a sapphire lens $\frac{1}{60}$th of an inch focus, combined with a glass lens $\frac{1}{10}$th of an inch focus.

On Fluid Doublets.

Fluid doublets.

Dr Wollaston's doublet, as shown in fig. 41, may be imitated with great facility by placing two plano-convex fluid lenses of different sizes upon plates of parallel glass.

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[1] Mr Coddington has shown that such a correction is impossible. (*Treatise on the Eye and Optical Instruments*, p. 55.)

In such an arrangement it is necessary in the fluid, as well as in the glass doublet, to have the axes of the lenses perfectly coincident; a result which, by the method already referred to, may be more accurately effected in the fluid one.

Pritchard's Triplet.

Pritchard's triplet.

Upon the same principle as the doublets, Mr Pritchard constructed triplets, the third or posterior lens having a longer focal length than the two others. This combination requires much more precision in the adjustment, and more attention in the centering. Mr Pritchard remarks, that, "when perfected, they amply repay the pains bestowed upon them, in the accuracy with which they exhibit the most difficult lined objects, though it is to be regretted that neither these nor the doublets of deep power will show pleasantly cylindrical bodies of large diameter, such as a large mouse or bat's hair." Having long made use of one of Mr Pritchard's triplets, we can amply confirm the account which he has given of the excellence of this combination. Mr Blackie has executed for us a triplet, the centre lens of which is garnet, the posterior one of quartz, and the anterior one of flat glass. It is a very powerful combination, and performs admirably.

Sir David Brewster has made triplets, in which two of the lenses are fluids and the third a solid, and some in which they are all fluids.

Gairdner's microscope.

A very simple method of fitting up doublets and triplets, or even single lenses, has been proposed by Dr William Gairdner of Edinburgh, and executed by Mr Bryson.

In this instrument a Wollaston's doublet A is fixed at the end of a handle AB. A ring C is attached to the end of a bent brass stem CD, which is secured to the handle AB at D. This ring contains a disc of thin glass, on either side of which objects may be placed for examination; fluids on the outside, and other objects on the inside of it. By means of a milled head M, the screw of which passes through the handle and acts upon the arm CD, the observer is enabled to bring the objects into the focus of the doublet. This little instrument has been recommended by botanists, physiologists, and medical practitioners.

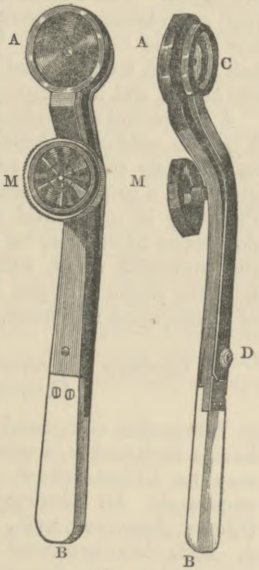

Fig. 42.

Single Achromatic Microscope.

Single achromatic microscopes.

In many of the doublets which we have already described, the chromatic aberration is partially, and sometimes greatly corrected, but still not to such a degree as to entitle them to the name of achromatic. The great improvement which has taken place in the art of grinding and polishing small lenses, has enabled the optician to execute *double* and *triple* achromatic lenses having a diameter so small as from $\frac{1}{4}$th to $\frac{1}{16}$th of an inch. Mr Pritchard has made them of the latter size with an angle of aperture of 65°. These lenses may be advantageously used in single microscopes where very high powers are not required, or when they cannot be applied, though it is usual to employ them as the object-glasses of compound microscopes, as we shall afterwards see.

Sir David Brewster has executed achromatic lenses, both *double* and *triple*, by combining a fluid *concave* lens with one or two convex lenses of the precious stones or glass. When the lenses are *double*, the fluid lens is of course a meniscus in which the concavity predominates, as it is impossible to form a fluid lens doubly concave.

Single Achromatic Fluid Microscope.

Single achromatic fluid microscope.

A single lens of glass, or of any of the gems, having a high refractive and low dispersive power may be made achromatic, or the colour much corrected, by suspending a fluid concave lens M upon a double convex lens L, as in fig. 43; CD being a plate of metal, or if the solid lens L is plano-convex, it may be cemented upon a plate of glass as in fig. 44. In order to increase the correcting power of the fluid lens M, we may make it doubly concave as in fig. 45; or AB may be a plano-convex lens with its plane side uppermost.

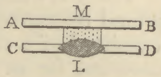

Fig. 43.

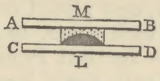

Fig. 44

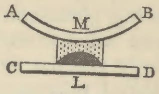

Fig. 45.

Fluid Achromatic Doublets.

Fluid achromatic doublets.

A fluid achromatic doublet may be made by placing a suitable fluid *mn* between the lenses, as in the annexed figures, in which all the lenses may be fluids, provided *mn* and the other fluids be immiscible.

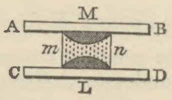

Fig. 46, *a*.

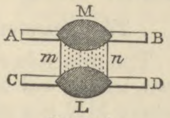

Fig. 46, *b*.

When M, L are of glass or precious stones, they may be set in brass plates.

Single Reflecting Microscopes.

Single reflecting miscroscopes.

Single reflecting microscopes are not much in use. They consist of a concave metallic speculum of a short focal length, so that any minute body placed in its focus will be seen magnified. The form of the speculum should of course be parabolic. Such a microscope is principally useful for looking at one's own eye, or any part of it not far from the pupil. In these cases no image is formed, as the rays enter the eye parallel.

Gray's.

The following ingenious contrivance for a fluid reflecting microseope we owe to Mr S. Gray (*Ph. Tr.* 1697, No. 228, p. 539). Having taken a small globule of quicksilver, and dissolved it in a menstruum of 10 parts of water and 1 of nitric acid (aquafortis), he dipped the end of a stick in this solution, and rubbed with it the inner circle of the ring A, so as to give it a mercurial tincture. This ring is made of brass, and is about the 30th of an inch thick, having its mean diameter not exceeding $\frac{2}{5}$ths of an inch. When the inner surface of the ring wetted with the solution has been wiped dry and laid upon a table, pour a drop of quicksilver within it, and when this drop is gently pressed with the ball of the finger it will adhere to the ring, and when cleansed with a hare's foot will form a *convex* speculum. If the ring and speculum are now taken up and carried horizontally, and laid on the margin of the hollow cylinder B, the mercury will become a *concave* reflecting speculum, in consequence of its upper surface sinking down by gravity. The cylinder B rests upon a pillar with a screw on its outside, and supported by the base D. A stage, ECFG, may be moved up and down, so as to place the object, which is fixed at G, in the focus of the concave speculum.

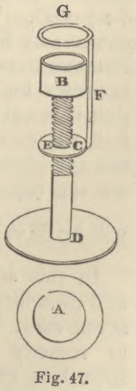

Fig. 47.

CHAPTER III.

ON COMPOUND MICROSCOPES.

Compound microscope.

A compound microscope is an instrument in which a distinct and enlarged image of an object is formed by an object-glass or a speculum, and this enlarged image again magnified by one or more eye-glasses.

There is every reason to believe, that the earliest compound microscopes which were used by Zansz and Galileo, consisted of a convex lens for an object-glass, and a concave one for an eye-glass, like the telescope which was at that time in use.

Fontana in 1646 used *two* convex lenses; Dr Hooke *three*, and Eustachio Divini *four;* the two next the eye being plano-convex, and placed in contact, with their convex sides towards each other, to give a high power and a large and flat field. In 1691 Philip Bonnani[1] used a compound microscope with three lenses, and added to it an illuminating apparatus with two lenses.

The reflecting compound microscope was first suggested by Sir Isaac Newton, and its construction varied and made more complex by Dr Barker and Dr Smith of Cambridge. The simple contrivance of Sir Isaac has in modern times been greatly improved by Amici, Potter, Tulley, Cuthbert, and Dr Goring.

The Common Compound Refracting Microscope.

Compound refracting microscope.

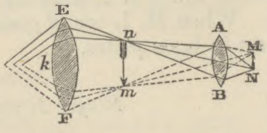

Fig. 48.

The principle of the common compound microscope with two lenses will be understood from the annexed figure, where MN is a minute object placed in the focus of the object-glass AB, or rather a little farther from it than its principal focus. An image of this object will be formed at *mn*, at some distance behind AB, the distance *n*A increasing as AM diminishes. The size of the image *mn* will be to that of the object MN as *n*A is to AM, their distances from the lens AB. If we now view this magnified image *mn* through an eye-glass EF, so placed that *mn* is in its principal focus, we shall again magnify it in the inverse proportion of E*n* to the distance at which the eye sees minute objects most distinctly, which is about 5 inches. The object MN is thus doubly magnified, so that if *n*A is six times AM, and the lens EF has a focal length of half an inch, the magnifying power will be $6\times\overline{5\div\frac{1}{2}}=60$. While the lenses are the same, the magnifying power may be increased to any extent by increasing the distance between the lenses EF and AB; but the object becomes indistinct as the magnifying power increases, so that it is not advisable to make the distance *n*A more than five, six, or seven inches; or calling *f* the focal distance of the eye-glass, D = AM, d = A*n*, and Δ the distance at which we see objects distinctly, then this magnifying power M will be $M=\frac{d}{D}\times\frac{\Delta}{f}$.

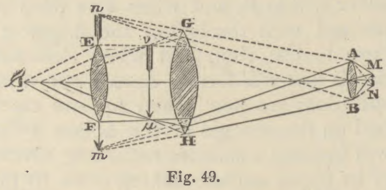

Fig. 49.

In this arrangement of lenses the field of view is small, and therefore we cannot see the whole of many small objects at one view. In order to remedy this, a large lens, called the amplifying glass, is placed between the image and the object-glass, as shown in fig. 49, where *nm* is the image formed by AB alone; but in consequence of the interposition of GH, it is contracted into $\nu\mu$, and this contracted image is magnified by the eye-glass EF.[1] In order to widen the field still farther, aud make it flat, two plano-convex lenses have been placed at E, F, having their convex sides in contact. In order to find the magnifying power when the lens GH is used, we must multiply the magnifying power, as obtained by the preceding formula, by the quantity $=\frac{L}{\phi}$, ϕ representing the focal length of the lens GH and $L=\frac{\delta^2}{\delta-\phi}-d-f$, δ being the distance between the first and second glasses, and d the distance between the first and third glasses.

Dr Goring prefers the following method of finding the magnifying power of these microscopes. Measure the aperture of the object-glass and call it a, make AM $=f$, and having measured with a micrometer scale the diameter of the usual pencil of rays before they enter the eye, call it d; then $a:f=d:$ F, F being the focal length of a single lens having the same power as the compound microscope. But the magnifying power m of a lens F is $\frac{\Delta}{F}$. Hence the magnifying power M of the compound microscope will be $M=\frac{\Delta a}{fa}$.

In the construction of this microscope some attention is requisite in adjusting the apertures of the object-glasses employed. The smaller they are, the less will be the spherical and chromatic aberration of the object-glass, but the less will be the light. When a plano-convex lens about half an inch focus is used, its plane side should be towards the object, and its aperture limited to $\frac{1}{15}$th of an inch.

A compound microscope is sometimes so constructed that it can be used on a single microscope stand. This is done by screwing the lower end of the body round the object-glass into a projecting arm at the top of the stand. When the body is unscrewed and removed, a single lens or a doublet or triplet may be screwed into the same place, and the moveable stage, with the slider and object, brought near the single lens, just as if it had been the object-glass of a compound microscope. (See fig. 3.)

Dr Goring's Improvement on the Object-Glass of the Compound Microscope.

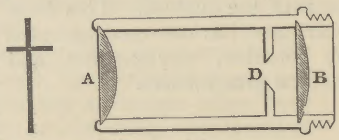

Fig. 50.

When the compound microscope does not require to have a high power, a compound object-glass of two lenses may be advantageously employed. Dr Goring (*Quart. Jour.* vol., xvii., p. 202) has contrived the combination shown in the annexed figure, where A is a plano-convex lens, with its flat side next the object, having its focal distance about one-half or two-thirds that of the plano or double convex lens B. A stop D is placed in the posterior focus of the object-glass A. Mr Pritchard remarks, that when the focal length of A "is not less than half an inch, this combination has been employed with considerable advantage, both as regards distinctness and aperture."

Mr Coddington's Improvement on the Eye-Glasses of the common Compound Microscope.

The improvement suggested by Mr Coddington on the eye-pieces of compound microscopes is shown in fig. 51.

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[1] Observationes circa viventia, quæ in rebus non viventibus reperiuntur.

[1] These two lenses, when plano-convex with their plane sides next the eye, and when their distance is equal to half the sum of their focal lengths, form the Huygenian eye-piece, which partially corrects chromatic and spherical aberration.

The object of the contrivance is to fulfil the condition proposed by Huygens in his excellent telescopic eye-piece; namely, to have the refraction of the pencils divided between the two lenses, and to produce the greatest possible flattening of the field. Mr Coddington found that the most proper form of the lenses was that shown in fig. 52, where the two eye-glasses consist of a meniscus A next the eye, and a double equi-convex lens B, while the field-glass is composed of two meniscuses C, D. Mr Coddington, however, informs us that he "found no sensible error arise from the substitution of plano-convex lenses for the meniscus-glasses, which are difficult and expensive to form." He remarks also, that theory indicates "a farther flattening of the field to be made by separating the eye-glasses a little, which requires the distance of the first eye-glass from the field-glass to be diminished by about half as much; but he did not perceive any improvement arising from this alteration in practice, and therefore he does not recommend the change. The object-glass which Mr Coddington uses in this microscope is the grooved sphere proposed by Sir David Brewster.

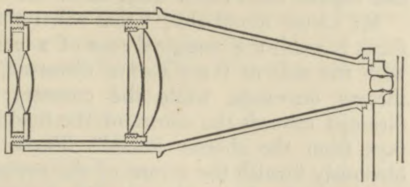

Fig. 51.

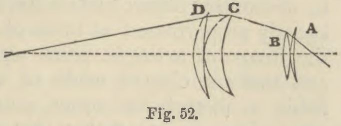

Fig. 52.

In his Treatise on the Eye and Optical Instruments Mr Coddington has proposed a different combination for the eye-glasses and the field or amplifying glass. Supposing the distance between the object-glass and field-glass to be 1 inch, the focal length of the field and eye-glasses 1 inch each, and the distance between the field-glass and nearest eye-glass 1 inch, he finds the distance of the two eye-glasses to be $\frac{3}{8}$th of an inch. He finds also, "that all indistinctness arising from the oblique refractions will be corrected when the field-glass is convexo-convex, nearly convexo-plane, the first eye-glass convexo-convex (the flattest side next the eye, radii as 3 : 1), and the second eye-glass a meniscus (the most convex side next the eye, radii as 1 : 5)."

Taking another case, he supposes the distance of the object-glass from the field-glass to be 2 inches, and the eye-glasses to be in contact, as in fig. 52; then "it appears that for the achromatism we must have the distance between the field-glass and the second eye-glass 1 inch." Then the field-glass must be convexo-plane nearly; the first eye-glass equi-convex, and the second eye-glass a meniscus with the radii as 1 : 5.

Dr Goring, who examined one of the instruments constructed on these principles, states, *that both the chromatic and spherical aberration of the objective part was wholly untouched, and that the eye-piece, consisting of four glasses, was achromatic.* He adds also, that nothing can surpass the beauty of the field of this microscope for extent of flatness. Now we think that Dr Goring has mistaken Mr Coddington, who never pretended to correct the spherical and chromatic aberration of the object-glass.[1] He considers the chromatic and spherical aberration of the grooved sphere, which is the object-glass he uses, as reduced to very small quantities, by leaving only a small channel in its axis for the passage of the rays. Whatever the residual aberration may be, Mr Coddington is not answerable for it, as his object was merely to make the other part of the microscope good, which, according to Dr Goring, he has succeeded in doing.

In accurate investigations with the microscope the instruments above described are of little use, and have been completely superseded by the compound achromatic microscope.

Compound Achromatic Microscope.

Compound achromatic microscope.

Although the achromatic microscope has only recently come into use as an effective and superior instrument, yet it can scarcely be considered as a new one. Every person knew that achromatic object-glasses were most desirable in the compound microscope. So early as 1776 Euler proposed to employ them in compound microscopes; but so late as 1821 M. Biot considered their introduction as out of the question, from the impracticability of making achromatic lenses as small as those which the microscope requires!

M. Selligues, 1823.

In 1823 M. Selligues and Dr Goring were both occupied with the subject, the former having employed MM. Chevalier, two excellent opticians in Paris, and the latter Mr Tulley, to execute small achromatic object-glasses. It is to M. Selligues, however, in so far as we can learn, that we are indebted for the new and happy idea of making the object-glass consist of *four* achromatic compound lenses, each consisting of two lenses. This idea is the actual source of the superiority of the achromatic microscopes; and in proof of this we may state, that Professor Amici, who had early been following out the old idea of a single achromatic object-glass, abandoned his attempts in 1815, but afterwards successfully resumed them by adopting M. Selligues' plan of the superposition of several object-glasses. In M. Selligues' instrument the focal length of each object-glass was 18 lines, its diameter 6 lines, and its thickness at the centre 6 lines. In that of Amici the focal length of each was about 6 lines; and MM. Chevalier have executed them having only 2 lines in focal length. More recently, however, Mr Pritchard has surpassed all these artists, by making them of one-sixteenth of an inch in focal length.

Amici.

From this brief historical detail we shall proceed to give a more minute account of the lenses executed by these different individuals, for which we are indebted to Mr Jackson Lister, whose able memoir on this subject is, as we shall see, one of the most valuable contributions to the science of the microscope that has for a long time appeared.

Chevalier.

The achromatic object-glasses of M. Selligues' microscope made by MM. Chevalier, consisted of a plano-concave lens of flint-glass, and a double convex one of crown or plate glass, with their inner curves cemented together by a mixture of mastic and turpentine, to remove the reflection of the interior surfaces, and prevent the introduction of dampness. Four of these lenses, of from $1\frac{1}{2}$ to $1\frac{7}{8}$ of an inch in focal length, were made to screw before each other, so as to be used either all together, or any of them individually, in the usual manner, like the object-glasses of a compound microscope. The aberration of colour was thus corrected in a considerable degree, but the glasses were fixed in their places, with their convex sides towards the object, which is their worst position; and in consequence of this the spherical aberration was enormous, and was distinctly seen, even with the small aperture to which it was necessary to reduce them.

Notwithstanding this defect, the grand idea of the combination was acquired; and M. Chevalier having observed the mistake committed by M. Selligues, made them of less focal length, and more achromatic; and turning the concave lens to the object, he produced in 1825 an instrument far above that of M. Selligues. His deepest glasses were four-tenths of an inch in focal length; and in his first microscope two such compound lenses were combined for his highest power.

Fraunhofer.

The date of Fraunhofer's achromatic microscopes is not known. Many years ago the writer of this article ordered an achromatic object-glass from Fraunhofer for a large microscope, for the purpose of making a particular class of observations; but at that time he seems not to have made any compound lenses to be combined after the manner of Selligues. Mr Robert Brown (*Phil. Trans.* 1830, p. 188) obtained a series of five such object-glasses from Utzschneider, whose focal lengths are from 1·8 to 0·43 of an inch.

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[1] *Treatise on the Eye and Optical Instruments*, pp. 58, 59, § 329.

Amici.

When Professor Amici visited London in 1827, he brought with him some compound object-glasses, which performed very well; and Mr Lister subsequently learned from him that he had executed a combination of 2·7 lines in focal length, and 2·7 lines in aperture, which greatly excels the former.

Lister.

Among the most successful improvers of the achromatic microscope we must rank Mr Jackson Lister, who has discovered some curious and valuable properties of these lenses that have escaped the notice of the most skilful analysis. Mr Lister has investigated the subject entirely as a matter of observation, and therefore his results are more likely to have a higher practical value.

Mr Lister takes as the basis of a microscopic object-glass two conditions,—1. that the flint-glass shall be plano-concave; and, 2. That it shall be joined by some cement to the convex lens. The *first* condition obviates the risk of error in centering the two curves; and the *second* diminishes by nearly a half the loss of light from reflection, which is very great at the numerous surfaces of a combination of compound object-glasses.

Now Mr Lister has found that in every such compound lens which he has tried, whether the flint-glass was Swiss or English, with a double convex of plate-glass, which has been rendered achromatic by the form given to the outer curve of plate-glass, the ratio between the refractive and dispersive powers has been such that its figure has been correct for rays issuing from some point in its axis not far from the principal focus on its plane side; and these rays either tend to a conjugate focus within the tube of the microscope, or emerge nearly parallel.

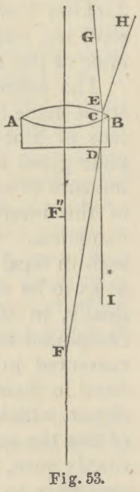

Fig. 53.

If AB represents such an object-glass, let us suppose that it is free from spherical and achromatic aberration for a ray FDEG radiating from F, then the angle of emergence GEH will be about three times as great as that of incidence FDI. If the radiant point is now made to approach the lens, the angles of incidence and emergence will approach to equality, and the spherical aberration produced by the two will bear a less proportion to the opposing error of the single correcting curve ABC, and hence in this case the rays will be *over-corrected* for such a focus.

As F continues to approach the lens, the angle of incidence continuing to increase, it will exceed that of emergence, which has been in the meantime diminishing, so that the spherical aberration produced by the two outer surfaces will recover their original proportion. When F has reached this point F″ (at which the angle of incidence does not exceed that of emergence so much as it had at first come short of it), the rays will again be free from spherical aberration. If F″ comes still nearer the lens, or is carried beyond F in the opposite direction, the angle of incidence in the former case, or of emergence in the latter, becomes disproportionately effective, and in either case the aberration exceeds the correction, or the rays are *under-corrected.* Hence Mr Lister gives the following rule:—

"*That in general an achromatic object-glass, of which the inner surfaces are in contact, or nearly so, will have on one side of it two foci in its axis, for the rays proceeding from which the spherical aberration will be truly corrected at a moderate aperture; that for the space between these two points, its spherical aberration will be over-corrected, and beyond them either way, under-corrected.*"

Mr Lister found also, "that when the longer aplanatic focus is used, the marginal rays of a pencil not coincident with the axis of the glass are distorted, so that a coma is thrown outwards, while the contrary effect of a coma directed towards the centre of the field is produced by the rays from the shorter focus." These interesting results obviously furnish the means of destroying both aberrations in a large focal pencil, and of thus surmounting what has been hitherto the chief obstacle to the perfection of the microscope. And when it is considered that the curves of its diminutive object-glasses have required to be at least as exactly proportioned as those of a large telescope, to give the image of a bright point equally sharp and colourless, and that any change made to correct one aberration was liable to disturb the other, some idea may be formed of what the amount of that obstacle would have been. It will, however, be evident, that if any object-glass is but made achromatic, with its lenses truly worked and cemented, so that their axes coincide, it may with certainty be connected with another possessing the same requisites, and of suitable focus, so that the combination shall be free from spherical error also in the centre of its field.

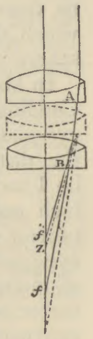

Fig. 54.

For this the rays have only to be received by the front glass B, from its shorter aplanatic focus *f*′, and transmitted in the direction of the larger correct pencil *f*A of the other glass A. It is desirable that the latter pencil should neither converge to a very short focus, nor be more than very slightly, if at all, divergent; and a little attention at first to the kind of glass used will keep it within this range, the denser flint being suited to the glasses of shorter focus and larger angle of aperture. If the two glasses, which in the diagram are drawn as at some distance apart, are brought nearer together (if the place of A, for instance, is carried to the dotted figure), the rays transmitted by B in the direction of the larger aplanatic pencil of A, will plainly be derived from some point (Z) more distant than *f*′, and lying between the aplanatic foci of B; therefore (according to what has been stated) this glass, and consequently the combination, will then be spherically over-corrected. If, on the other hand, the distance between A and B is increased, the opposite effects are of course produced.

In combining several glasses together, it is often convenient to transmit an under-corrected pencil from the front glass, and to counteract its error by over-correction in the middle one.

Slight errors in colour may, in the same manner, be destroyed by opposite ones; and, on the principles described, we not only acquire fine correction for the central ray, but, by the opposite effects at the two foci in the transverse pencil, all coma can be destroyed, and the whole field rendered beautifully flat and distinct. (*Phil. Trans.*, 1830, p. 199.)

Compound Achromatic Microscopes with Solid and Fluid Lenses.

Compound fluid achromatic microscope.

In 1812 a very simple method was employed by Sir David Brewster for making both single and compound achromatic microscopes. Almost all objects are seen to the greatest advantage when immersed in a fluid, even the finest test objects, such as the scales of the Podura. Having placed the object on a piece of glass, he put above it a drop of an oil having a greater dispersive power than the single lens, or than the concave lens which formed the object-glass of the microscope. The lens was then made to touch the fluid, so that the surface of the fluid was, as it were, formed into a concave lens. Now if the radius of the outward surface of this lens was such as to correct the dispersion, we have here a perfect achromatic microscope, both simple and compound. The best way is to over-correct the colour of the plate-glass lens by the fluid, and then to reduce the dispersion of the fluid by mixing it with one of a less dispersive power. This will be understood from the annexed diagram, where AB is an unequally convex lens, the flattest side of which is plunged in the fluid *mn*, placed in a watch-glass CD. The object is placed at *mn*, and the dispersion of the concave surface of the fluid compensates that which is produced by the lens. All errors of centring are here removed, and also the loss of light at the touching surfaces of solid lenses. If AB is a single microscope, the object *mn* will be placed in its principal focus, and the emergent parallel rays will enter the eye; but if it is the object-glass of a compound microscope, an image will be formed a few inches behind AB, by withdrawing AB a little from *mn*, or placing the object a little without its principal focus. We have already had occasion to describe an achromatic grooved sphere, but in the process of achromatizing it, the sphere loses in a very small degree its valuable property of refracting in the very same manner all the pencils that enter the eye. This property, however, may be preserved in the bird's-eye sphere by the achromatic method which we have now described. Let AB (fig. 56) be the grooved sphere, and CD the watch-glass containing the fluid; it is obvious that every ray which passes through the centre of the sphere will enter and quit it perpendicularly, without suffering any refraction. The same mode of achromatizing the sphere AB may be adopted with a solid concentric concave lens of flint-glass or other substance, or the sphere may be placed between two such concentric lenses. The greater the dispersion of the flint-glass, the nearer must the outer surface CD approach to AB. By these means the grooved sphere may be rendered perfect, both as a single microscope and as the object-glass of a compound one.

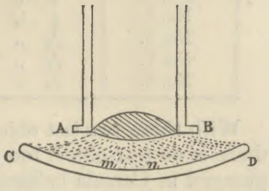

Fig. 55.

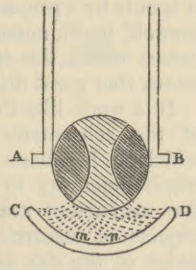

Fig. 56.

The principle above described may be applied to a system of object-glasses like those of Selligues' microscope. Let A, B, E (fig. 57) be three convex lenses, so placed at the end of the tube of a compound microscope, that the highly dispersive fluid in the watch-glass CD will enter between the glasses A, B, and E. The concave lenses of fluid will over-correct the three lenses A, B, and E; but if a very deep curvature on the outside of A is not sufficient to compensate this over-correction, it may be effected by a suitable lens at F. If the three lenses are made of the precious stones, with a high refractive power and a low dispersive one, the concave fluid lenses will not over-correct them.

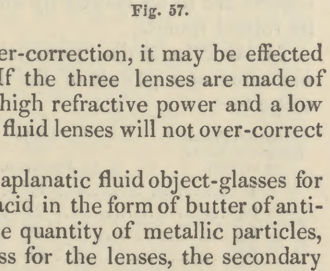

Fig. 57.

If, as Dr Blair did in his aplanatic fluid object-glasses for telescopes, we use muriatic acid in the form of butter of antimony, and containing a due quantity of metallic particles, for the fluid, and crown-glass for the lenses, the secondary colours will be completely corrected, and an instrument of the most superior kind produced. If a permanent and portable *aplanatic* object-glass is preferred, the butter of antimony may be placed between a meniscus and a plano-convex lens of crown glass, as in the annexed figure, where *o* is the object, CD a meniscus of crown-glass, AB a plano-convex lens, and *mn* a concave lens of the fluid. This construction of the object-glasses of compound microscopes is much more easily applicable in the case of the microscope than in that of the telescope. In the latter case the colour of the fluid, the changes which it undergoes by time, and the difficulty of retaining it, are objections of considerable amount; but in the case of the microscope, the colour of the fluid disappears owing to its small thickness, and it may be retained by capillary attraction alone, and renewed as often as we choose.

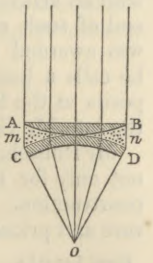

Fig. 58.

Recent improvements on the microscope.

Since these observations were published, the compound achromatic microscope has undergone great improvements in the hands of Pritchard, Ross, Powell, Messrs Smith and Beck, M. Nachet, MM. Oberhauser, and Professor Amici of Florence. These great improvements, by which the compound achromatic microscope has been brought to such a high degree of perfection, were no doubt owing to the spirit of competition excited by the London and Paris Exhibitions.

In the Crystal Palace of 1851, Mr Andrew Ross, Messrs Smith and Beck, and M. Nachet of Paris, were the leading competitors. Mr Ross and Messrs Smith and Beck received council medals, and M. Nachet a prize medal. The instruments of the first two artists were of first-rate quality, and those of M. Nachet were superior to those of all foreign opticians. The following tables show the relative angles of aperture and focal lengths of the object-glasses exhibited by the competitors:—

Mr Ross's.

Mr Ross's Object-Glasses in 1851.

Focal Lengths.	Angles of Aperture.
1 inch	27 degrees.
0 $\frac{1}{2}$,,	60 ,,
0 $\frac{1}{5}$,,	113 ,,
0 $\frac{1}{8}$,,	107 ,,
0 $\frac{1}{12}$,,	135 ,,

Messrs Smith and Beck's.

Messrs Smith and Beck's Object-Glasses in 1851.

Focal Lengths.	Angles of Aperture.
0 $\frac{2}{3}$ inch	45 degrees.
0 $\frac{4}{10}$,,	70 to 75 ,,
0 $\frac{4}{10}$,,	60 ,,
0 $\frac{1}{5}$,,	100 to 105 ,,

M. Nachet's

M. Nachet's Object-Glasses in 1851.

Focal Lengths.	Angles of Aperture.
0 $\frac{1}{5}$ inch	88 degrees.
0 $\frac{1}{8}$,,	108 ,,
0 $\frac{1}{18}$,,	134 ,,

Mr Ross intended to exhibit in Paris object-glasses of a still higher order than those which we have mentioned, and he would thus have found himself in competition with his eminent rivals Messrs Smith and Beck, and M. Nachet. He was prevented, however, by the pressure of business from exhibiting the new object-glass which he had prepared for that purpose; and Messrs Smith and Beck, who had no English rival, carried off the microscopic prize by receiving a medal of the first class. Although the microscope of M. Nachet was not equal to that of the English artists, it had such a high degree of merit that a medal of the same value was adjudged to him.

Oberhauser's.

MM. Oberhauser of Paris exhibited an excellent achromatic microscope, and also one intended for observations in the vacuum of an air-pump, for which a medal of the first class was adjudged.

Mr Pillischer's microscopes.

Mr Pillischer of Bond Street exhibited a microscope with an achromatic object-glass half an inch in focal length, and of such excellence that a medal of the second class was awarded to him. Mr Pillischer also exhibited what he calls a lenticular microscope, for examining urinary deposits at the bedside, which has been highly spoken of by the late Mr Golding Bird and Mr Quekett.

Mr Pillischer's "students' microscopes" were remarkable, not only for their cheapness, but the excellence of their construction. The following is a list of the angles of aperture and prices of his object-glasses :—

Focal Lengths.	Angles of Aperture.	Prices.
2 inches	14 degrees	L.2 2
1 ,,	26	2 2
$0\frac{1}{2}$,,	60	4 0
$0\frac{1}{4}$,,	90	5 0
$0\frac{1}{5}$,,	109	5 0

The following table contains a description of the achromatic object-glasses which Mr Ross intended to exhibit :—

Mr Ross's new object-glasses.

Mr Ross's new Object-Glasses in 1855.

Object-Glasses. Focal Lengths.	Angles of Aperture.	Magnifying Powers with four Eye-Pieces.				Prices.
		A.	B.	C.	D.	
2 inches.	12 degrs.	20	30	40	60	L.3 0 0
1 ,,	15 ,,	60	80	100	120	3 0 0
1 ,,	22 ,,	60	80	100	120	3 10 0
$0\frac{1}{2}$,,	65 ,,	100	130	180	220	5 5 0
$0\frac{1}{4}$,,	85 ,,	220	350	500	620	5 5 0
$0\frac{1}{4}$,,	125 ,,	220	350	500	620	7 10 0
$0\frac{1}{6}$,,	135 ,,	320	510	700	910	10 0 0
$0\frac{1}{8}$,,	130 ,,	400	670	900	1200	11 0 0
$0\frac{1}{8}$,,	150 ,,	400	670	900	1200	12 0 0
$0\frac{1}{12}$,,	170 ,,	650	900	1250	2000	18 0 0

Messrs Smith and Beck's.

Messrs Smith and Beck sent two achromatic microscopes to the Paris Exposition, namely, one of their very best instruments, and another of an entirely new construction, to which they gave the name of "The Educational Microscope."

The first of these microscopes differed very little from the one which they exhibited in 1851 at the Crystal Palace. It had, however, object-glasses of a shorter focus and greater angular aperture, as is shown in the following list :—

Focal Lengths.	Angles of Aperture.
$1\frac{1}{2}$ inches	13 degrees.
$0\frac{2}{3}$,,	27 ,,
$0\frac{4}{10}$,,	90 ,,
$0\frac{1}{5}$,,	110 ,,
$0\frac{1}{8}$,,	120 ,,

Educational microscopes.

The Educational Microscope exhibited by Messrs Smith and Beck is an instrument of great value, and from its low price and excellence it cannot fail to have an extensive sale. With object-glasses of one inch and a quarter, and apertures of 22° and 75°, its price, packed in a case, is only 1 .10, and the additional apparatus, including one Lieberkhun, a Wenham's parabolic reflector, a Wollaston's camera lucida for drawing, and a polarizing apparatus complete, with prisms of selenite, amount only to L.5 additional. Since the middle of 1855 no fewer than 100 of these educational microscopes have been sold, and two-thirds of this number had the additional apparatus.

M. Nachet's object-glasses.

The following were the object-glasses which M. Nachet exhibited in 1855, and which were much admired by the jury :—

Series.	Focal Lengths.	Angles of Aperture.	Prices.
No. 3.	$\frac{1}{4}$ inch	75°	L.2 10 0
No. 4.	$\frac{1}{6}$,,	90	2 10 0
No. 5.	$\frac{1}{8}$,,	95	3 3 0
No. 6.	$\frac{1}{10}$,,	110	4 0 0
No. 7.	$\frac{1}{14}$,,	125	5 5 0
No. 8.	$\frac{1}{18}$,,	165	7 5 0

With these two last object-glasses M. Nachet states that there is no test-object too difficult to be resolved when it is plunged in Canada balsam.

Fine microscope shown to the jury by Prof. Amici.

When the jury of Class VIII. were comparing the rival microscopes, Professor Amici of Florence, distinguished by his optical inventions, showed a microscope which exhibited certain striæ in test-objects better than any of the instruments under examination. This superiority was produced by the introduction of water between the object and the object-glass; but as Professor Amici was not an exhibitor, the jury was not called upon to adjudicate to him a medal.

His achromatic microscopes.

This microscope was of small dimensions compared with those with which it was compared, and shows how much may be effected by the ingenuity and optical knowledge of an observer like Professor Amici, thoroughly acquainted with optics. We have seen at Florence, in Professor Amici's studio, instruments of his construction which exhibit distinctly the lines in certain objects which have hardly been seen by other instruments; and we are convinced that it is only by a preparation of difficult objects by the observer himself, by illuminating them properly, and by optical processes which the optician neither knows nor pretends to know, that great discoveries are to be made.

In a work like this we cannot find room for an account of the achromatic microscope in the various forms in which it has been constructed. Every artist has shown much ingenuity in the construction of different parts of the instrument and in the adaptation of it to different objects of research, and the naturalist will be the best judge of the size and nature of the instrument which he wishes to employ. We shall therefore content ourselves with describing one of the earliest achromatic microscopes, namely, that of Mr Pritchard; the latest, and what we believe to be the best, namely, that of Mr Andrew Ross; and some forms of the instrument which possess special advantages.

Pritchard's Compound Achromatic Microscope.

Pritchard's compound achromatic microscope.

This instrument is represented in fig. 59 as fitted up by Mr Pritchard. All its parts are so distinctly shown in the figure that they require no description, especially as the uses of most of the parts have been described in a former chapter. Fig. 59 is a perspective view of the instrument in its most convenient position for examining transparent objects by reflected light. The stops and condensing illuminator, which are seen under the stage, should be removed when particular objects are to be examined. When test-objects are to be viewed by direct light the instrument can be turned round.

In Mr Pritchard's instrument the following are the dimensions and powers of the lenses for a complete microscope :—

Sidereal Focal Length in parts of an inch.	Angle of Aperture.	Magnifying Powers in Diameters by a standard of 5 inches.
1	16°	60 to 100
$0\frac{1}{2}$	21	100 to 360
$0\frac{1}{4}$	42	240 to 500
$0\frac{1}{8}$	55	500 to 1100
$0\frac{1}{16}$	65	900 to 3000

Of these object-glasses, that whose focal length is $\frac{1}{4}$th of an inch appears to be the most perfect and useful.

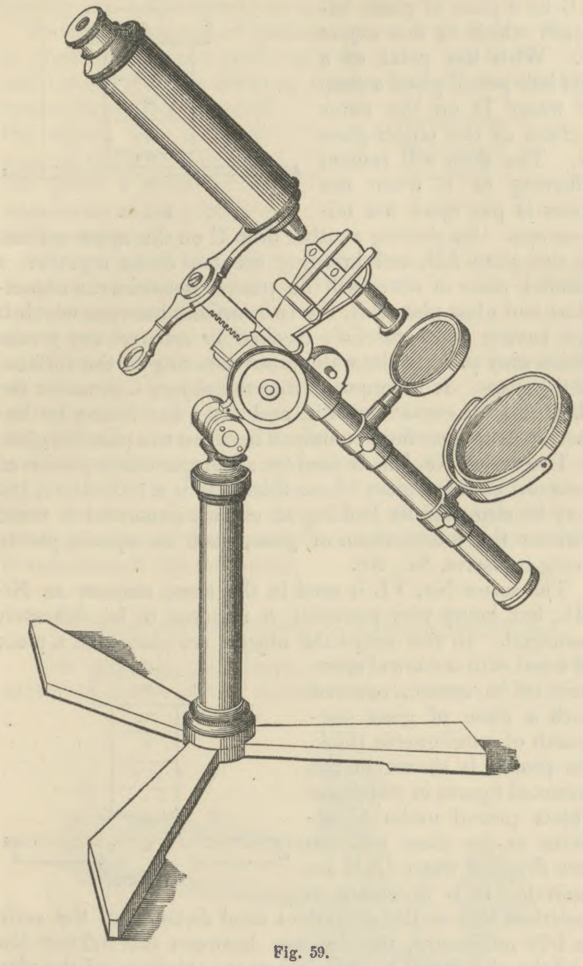

Fig. 59.

Mr Andrew Ross's Compound Achromatic Microscope.

Ross's microscope.

The great achromatic microscope of Mr Andrew Ross, in its most perfect and recent form, is shown in fig. 60.

The body of the microscope AB rests upon a massive stand so constructed as to prevent any perceptible tremor in the object under examination. The transverse arm *mn* into which it is screwed at *m*, is fixed by a screw E to the top of a strong flat bar, in the back of which is a rack into which works a pinion moved by the milled head M, which gives the *coarse* adjustment for bringing the body of the microscope into focus. Another milled head on the opposite side enables the observer to do the same thing with his left hand. The fine adjustment, for obtaining distinct vision of the object, is effected by the milled head C, which acts upon the tube at B, into which the object-glasses are screwed, one turn of it giving a motion of the 300th of an inch. On the top of the two pillars P, P is fixed a horizontal axis D, which passes nearly through the centre of gravity of the microscope, and upon which it turns, so that it may be placed at any angle whatever to the horizon. The stage S for holding the object, and the apparatus beneath it for modifying the light to illuminate the object, are most ingeniously constructed. The two rectangular or traversing motions of the stage are produced by the two milled heads below B. The secondary stage at T, for condensing and modifying the light reflected from the mirror V, receives all the requisite motions from the milled heads shown in the figure. In the cylindrical tube of which it is composed is placed the achromatic condenser and one of the polarizing prisms or rhombs, and other pieces of apparatus which are often required in particular researches.

Without depreciating the fine instruments of Smith and Beck, and Powell and Lealand, which evince great ingenuity, and have many new and admirable properties, the microscope of Mr Ross must be regarded as the finest hitherto constructed.

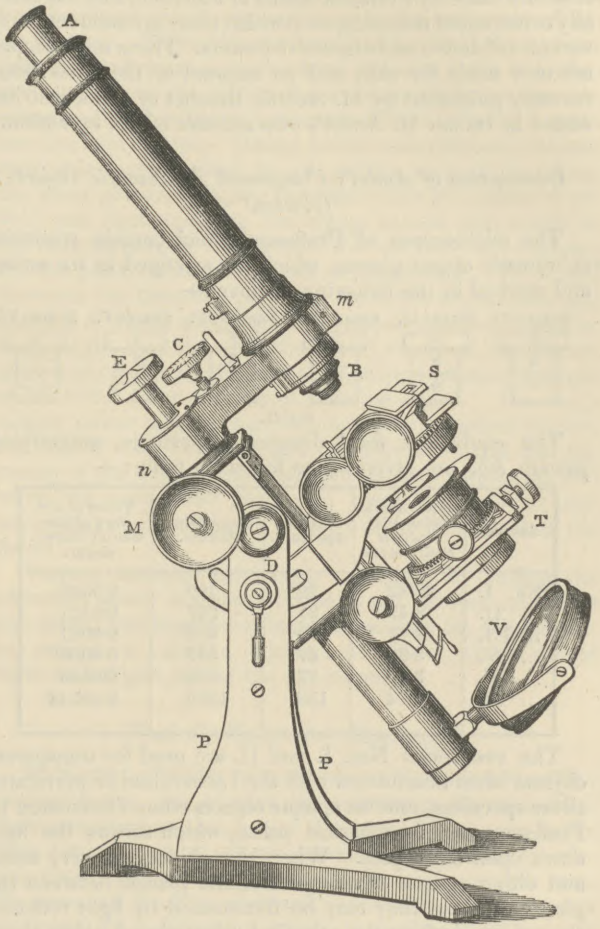

Fig. 60.

The future of the microscope.

The compound achromatic microscope may be considered as having nearly attained to perfection, while the practical optician confines himself to the use of flint and crown-glass lenses with spherical surfaces. It is hardly possible, however, that so noble an instrument, by which so much knowledge has yet to be acquired, will long remain in its present imperfect state.

The writer of this article has long ago, and repeatedly, urged upon the optician the necessity of constructing both telescopes and microscopes upon the aplanatic principle discovered by Dr Blair, a principle much more easily applied to small than to large object-glasses. Science has fully performed her part in showing how the colours of refracted light, both primary and secondary, may be corrected, but neither public liberality nor private enterprise has been called forth to put in practice her methods. Even in the case of the primary colours opticians have declined to take the trouble of making each lens of their eye-pieces achromatic, and, with one exception, they seem not even to have attempted to correct the errors of the secondary spectrum. The time, however, has now come to make this attempt; and we have no doubt that before the close of the century we shall have—what Dr Blair neither anticipated nor proposed to have—each lens of our optical instruments perfectly aplanatic, even if the art of grinding surfaces otherwise than spherical has not been discovered.

The employment of fluids of various dispersive powers gives the artist a wider range in his experimental researches, but even if he limits himself to the use of different kinds of glass and transparent minerals, we have no doubt of his ultimate success. This attempt has been boldly and so far successfully made by Professor Amici of Florence, who has actually constructed microscopes in which there are solid lenses of various refractive and dispersive powers. These microscopes are now made for sale, and an account of them has been recently published by M. Achille Brachet of Paris, who has added in Italian M. Amici's own account of his invention.

Description of Amici's Compound Achromatic Object-Glasses.[1]

Amici's achromatic object-glasses.

The microscopes of Professor Amici contain *seventeen* achromatic object-glasses, which are arranged in *six* series, and marked in the following manner:—

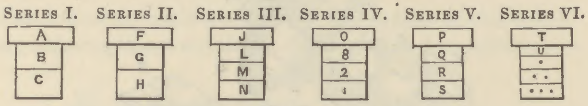

Fig. 61.

The equivalent focal distances, apertures, magnifying powers, &c., are given in the following table:—

SERIES.	Equivalent Focal Distance in Millimetres.	Angular Aperture.	Magnifying Powers.	Value of one part of the Ocular Micrometer.
No. I.	22·82	26°	100	0·0326
... II.	8·47	37	257	0·0121
... III.	4·27	70	535	0·0061
... IV.	3·92	57	577	0·0056
... V.	3·50	77	650	0·0050
... VI.	1·74	160	1310	0·00248

The two series Nos. I. and II. are used for transparent objects when illuminated with the Lieberkhun or perforated silver speculum, and for opaque objects when illuminated by Professor Amici's spherical prism, which throws the light down upon the object. When the objects are very small, and either opaque or transparent, and placed between two plates of glass, they may be illuminated by light reflected very obliquely from the spherical prism placed below them, and they are seen on a dark ground when the prism gives an obliquity greater than the angle of aperture of the object-glass employed. In the series No. I., for example, where half the angle of aperture is 13°, if the lower illuminating spherical prism is more than 13° distant from the optic axis, none of the refracted light will reach the eye, and the object will radiate only the light which its surface is capable of reflecting. This mode of illumination, which often produces an excellent effect, may be used with the series No. VI.

The series No. IV. is used for naked transparent objects, or when they are not covered with a plate of glass,—at least with one not very thin.

The series No. V. is used for transparent objects covered with a plate of glass 0·86 of a millimetre thick, of which there is a dozen. If a plate thicker than this—a millimetre, for example—is used, the object will be seen less distinctly.

The series Nos. III. and VI. are constructed on a new principle, which renders the image more clear and distinct, and does not require any correction of the error which the common system introduces, owing to the different thicknesses of the plates of parallel glass which cover the object. This advantage is obtained by immersing in a drop of distilled water the last lower surface of the series III. and VI. This operation is performed in the following manner:—Let AB be a plate of glass, beneath which is the object C. With the point of a wet hair pencil place a drop of water D on the outer surface of the object-glass N. The drop will remain adhering to it when the series is put upon the microscope. By putting another drop C on the upper surface of the plate AB, and bringing the two drops together, a parallel plate of water will be placed between the object-glass and glass plate AB, the two surfaces between which it lies having been carefully cleaned to remove any grease which may prevent the water from adhering to the surfaces of the glass. It is supposed that the object C is under the plate AB, in contact with it, and dry; but it may be immersed in another fluid contained between two plates of glass.

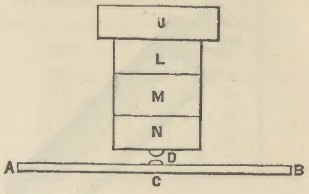

Fig. 62.

The series No. III. is used for all preparations preserved between plates of glass whose thickness is a millimetre, and may be also used for looking at objects immersed in water without the interposition of glass, such as aquatic plants, living infusoria, &c., &c.

The series No. VI. is used in the same manner as No. III., but being very powerful, it requires to be delicately managed. In this series the objects are placed on a piece of wood with a conical aperture in its centre, covered with a plate of glass one-fourth of a millimetre thick. Its profile is shown in the annexed figure, in which the object placed under C adheres to the glass, and the two drops of water D, E are united. It is necessary to mention, that as the equivalent focal distance of the series is 1·74 millimetre, the distance between the inferior lens and the object will be 0·4; and as the thickness of the plate of glass is one-fourth of a millimetre, or 0·25, the distance between the object-glass and the glass plate—that is, the thickness of the plate of water—will be only 0·15, a distance so small that the greatest care is necessary in finding the object, in order that the very thin glass may not be broken. If this does happen, we must substitute another of the same thickness, as measured by the spherometer.

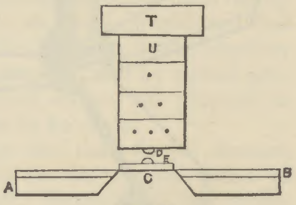

Fig. 63.

The series may also be used for any other thickness of glass less than 0·4, and down to zero, that is, when there is no glass over the object placed in water; but the effect is the best when the thickness of the glass is 0·25, as in this case the achromatism is perfect, even at the obliquity of $\frac{160^\circ}{2}=80^\circ$ with the optical axis, in which case we can see striæ or parallel lines whose distance is equal to $\frac{1}{6000}$th of a line, or $\frac{1}{72000}$ th of an inch.

If the object to be examined is in a fluid, such as the globules of blood, take a fragment of thin glass, a line or two in diameter, and place upon it the blood; it will, when put in contact with the plate on C, adhere to it by attraction, and retain its fluidity for many hours.

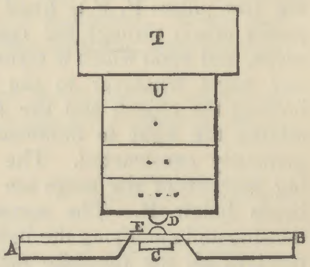

Fig. 64.

If we have occasion to look at any object with No. VI., when it is covered with very thin glass, or when it is in water, without the interposition of glass, the vision will be improved by removing the object-glass U, and leaving the series formed as in fig. 65.

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[1] *Simples Preliminaires sur le Commentaire de la Notice du Meilleur Microscope Dioptrique, composé Achromatique du Professeur Amici.* Par M. Achille Brachet. Paris, 1856.

Professor Amici is of opinion that no object-glass hitherto constructed has a power as great as his series No. VI.; and considering the distance (about 0·4) which is left between the object-glass and the object, with an aperture of 160°, he thinks he has given a proof of the superiority of the principle he has invented.

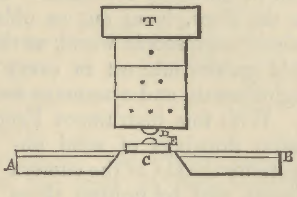

Fig. 65.

Professor Amici has not described the principle here referred to, nor mentioned the transparent substances of which his object-glasses are composed. He merely tells us that Nos. I. and II. are constructed with *four* different refractive and dispersive substances; Nos. III., IV., and V., with *five*; and No. VI. with *six* such substances.

In illuminating transparent objects Professor Amici uses only a single lens of flint-glass or rock-crystal, and maintains the strange opinion, contrary to theory as well as to the experience of every practical optician, that achromatic illumination is not necessary.

Professor Amici's Pocket Achromatic Microscope.

Amici's pocket achromatic microscope.

This portable microscope, which we have found very useful, is shown in the annexed figure, where AB is the

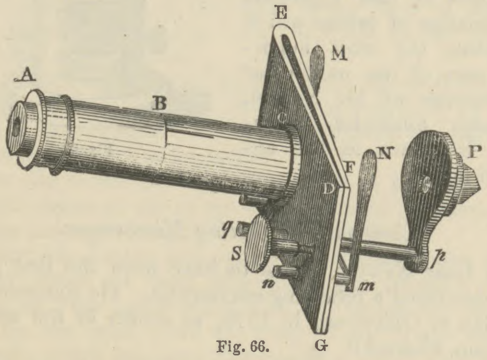

Fig. 66.

body of the microscope, 2½ inches long, sliding into the tube BC, $\frac{6}{10}$ths of an inch in diameter. The tube BC screws into the doubled plate of brass EDG, 2½ by 1½ inches, which acts as a spring, and may be opened or shut by the screw-nut S, for the purpose of moving the stage or object-holder MN*mn* towards or from the object-glass. This stage is a spring which holds the object-plate firm, by pressure; two pins *mn*, at the lower end of each arm N, M, sliding through holes in the plate EDG. When the object-plate is placed between MN and EF, and fixed by pressing the two plates together, the tube may be held horizontally, and distinct vision obtained by the motion of the body AB in the tube BC, and by the finer motion given by turning the screw-nut S, which shuts or opens the spring DEF, and places the object nearer or farther from the object-glass.

When it is desired to hold the microscope vertically, the object is illuminated by a rectangular prism P*p* attached to an arm *pq*, which slides in a little spring tube fixed in the plate EDG. The side of the prism next the object-glass is convex, for the purpose of condensing the rays which fall upon it.

The Microscopic Finder.

The microscopic finder.

Professor Amici has referred, in the description of his series No. VI., to the great difficulty of finding the object and placing it on the point of sight, and to the great danger of breaking the thin glass of the object-plate, owing to the distance between it and the object-glass being only 0·15 of a millimetre, or the $\frac{1}{170}$th part of an inch. A microscope, indeed, requires a finder as much as a telescope; but, in so far as we know, no person has attempted to give it one.[1]

We obviously cannot with advantage attach a second microscope to the principal one, as is done in the telescope; but the object may be gained in a simpler and more effective manner. When the observer is using his highest power both of object-glass and eye-piece, and loses sight, as he frequently does, of the object, or part of an object, under examination, he often finds it extremely difficult to bring it again into the field of view. Owing to the unsteadiness of almost every microscopic stand, he will seldom succeed by taking the lower powers, bringing the object into the centre of the field, and then replacing the higher powers with which he has been viewing it. But even if this method were successful, the labour which it imposes is intolerable. Sir David Brewster has therefore proposed the following method, and found it perfectly successful:—A concave lens of a greater focal length than the equivalent focal length of the object-glass is slipped upon the tube of the object-glass, or brought in front of it when withdrawn from the object. The magnifying power may be thus reduced in any required degree, the field of view enlarged, and the object brought into the centre of the field; the concave lens is then withdrawn, and when the instrument has been readjusted without any movement of its parts, the object will be found within the field.[2]

Various methods have been described for finding the object by means of scales, horizontal and vertical, applied to the slides; but however valuable these may be, the apparatus cannot be called a Microscopic Finder, which should form an integral part of the instrument.

Nachet's Multocular Microscopes.

Nachet's multocular microscopes.

M. Nachet, of whose microscopes we have already spoken in high terms, has adapted the microscope for anatomical demonstrations, so that two or three persons may see at the same time the result of microscopical dissections, by constructing two microscopes—a *double* and a *triple* one. By means of the first, one person can examine the progress and result of a dissection which is performed by another person; and by means of the second, two persons can enjoy this advantage.

In the microscope for two persons this result is obtained by placing above the object-glass a prism P (fig. 67), the section of which is an equilateral triangle. The rays from the object-glass, shown in the figure by the letter *ab*, *a′b′*, entering the lower face of the prism perpendicularly, the two halves of the pencil are reflected in opposite directions from the other faces of the prism at angles of 45°, and thus enter the two separate tubes, in each of which they form an image of the object. These images are in a certain sense erect; but in order to see them in exactly their natural position, in which case alone the ana-

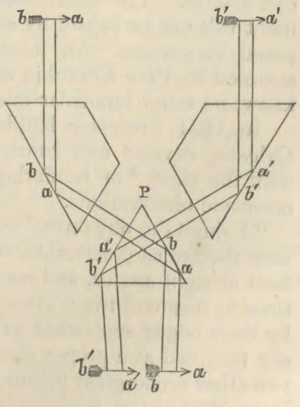

Fig. 67.

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[1] See Brewster's *Treatise on Optics*, p. 486, edit. 1853.

[2] Opticians will adopt various modes of applying and withdrawing the concave lens.

tomist can use his scalpel, a prism is placed in each tube between the former prism and the eye-pieces, so that their planes of reflection are perpendicular to those of the other prisms. By this means the images are perfectly erect, and the demonstrator can proceed with his work without fatigue or difficulty. If the demonstrator and observer should have eyes of different focal lengths, the adjustment is effected by moving the eye-piece to or from the object-glass.

When the microscope is constructed for three persons, the pencil of rays from the object-glass is divided by three prisms placed in the same plane, and whose reflecting faces, if brought together, would form a triangular pyramid. The pencil from the object-glass is then divided and directed into three separate tubes, in which three prisms erect the three images, and place them in their natural position. This instrument is shown in the annexed figure.

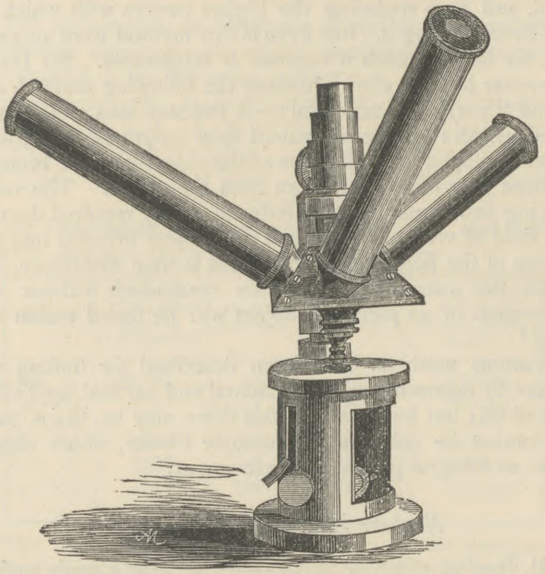

Fig. 68.

M. Nachet has also constructed the instrument for the use of *four* persons.[1]

Nachet's Binocular Microscope.

Nachet's binocular microscope.

The idea of a binocular microscope can hardly be called an invention, if constructed on the same principle as the binocular telescope with two object-glasses as well as two eye-glasses. The additional expense of such an instrument will not be repaid by any advantage which it is supposed to possess. An instrument of this kind was constructed by Père Cherubin about 1670; but in so far as we know, no other binocular microscope has been made.

In 1851 Professor Riddell, of the university of New Orleans, devised and constructed a binocular microscope with the view "of rendering both eyes serviceable in microscopic observations."

Professor Riddell's, of New Orleans.

"Behind the objective," says Professor Riddell, "and as near thereto as practicable, the light is equally divided and bent at right angles, and made to travel in opposite directions by means of two rectangular prisms which are in contact by their edges somewhat ground away; the reflected rays are received at a proper distance for binocular vision upon two other rectangular prisms, and again bent at right angles, being thus either completely inverted for an inverted microscope, or restored to their first direction for the direct microscope."

"With these instruments," the author adds, "the microscopic dissecting knife can be exactly guided. In looking at microscopic animal tissues, the single eye may perhaps behold a confused amorphous or nebulous mass, which the pair of eyes instantly shapes into delicate superimposed membranes with intervening spaces, the thickness of which can be correctly estimated. Blood corpuscles, usually seen as flat discs, loom out as oblate spheroids. In brief, the whole microscopic world, as thus displayed, acquires a tenfold greater interest in every phase, exhibiting in a new light beauty and symmetry indescribable."

With this instrument Professor Riddell obtained dissimilar drawings of solid objects by the aid of the camera lucida, and by uniting them in the stereoscope he brought them out in their natural relief.

When the two tubes of M. Nachet's double microscope are placed vertically and parallel to one another, and are brought so near to the central prism that their distance is equal to 2½ inches, the distance between the two eyes, the instrument becomes a binocular one, similar to that of Professor Riddell, to whom we must ascribe the invention of that ingenious combination of prisms which constitute the most important part of the multocular microscopes of M. Nachet. Nachet's binocular instrument is shown in the annexed figure.

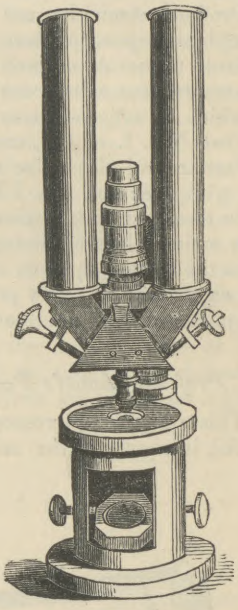

Fig. 69.

Compound Reflecting Microscopes.

Compound reflecting microscope.

Sir Isaac Newton seems to have been the first person who described a reflecting microscope. He communicated his plan to Oldenburg in 1679, as shown in the annexed diagram, where AB is a concave speculum, O the object, F the place where an image of it is formed, and CD an eye-glass for magnifying it. In another letter to Oldenburg, dated 11th July of the same year, he refers to another improvement on microscopes, which is to "illuminate the object in a darkened room, with *the light of any convenient colour, not too much compounded;* for by that means the microscope will, with distinctness, have a deeper charge and larger aperture, especially if its construction be such as I may hereafter describe." We are not aware that this idea was ever further developed by its author.[1]

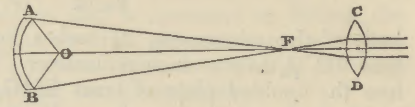

Fig. 70.

Mr Potter's Improvement upon it.

Potter's improvement.

Mr Potter[2] has recently proposed "a new construction of Sir Isaac Newton's microscope," principally with the view of removing the difficulty of illuminating the object. His first construction was for opaque objects; and in order to illuminate them, he cut a large circular aperture *abc* in the tube, between the object and the speculum; but the light which fell on the sides of the tube occasioned a good deal of indistinctness in the field of view. This defect, however, was completely removed by lining all the lower

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[1] The use of Multocular instruments was proposed by Sir David Brewster in 1822. (See *Edinburgh Philosophical Journal* 1822, vol. vii., p. 327; and Coddington's *Elementary Treatise on Optics*, p. 133.)

[1] Brewster's *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton*, vol. i., p. 242.

[2] *Edinburgh Journal of Science*, Jan. 1832, No. 11, p. 61.

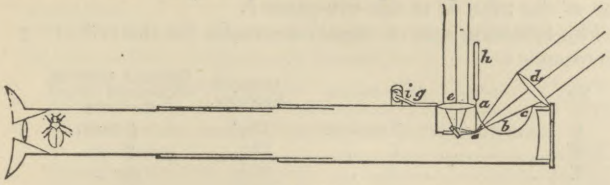

Fig. 71.

parts of the tube with black velvet. Mr Potter found it advantageous to concentrate the light on those objects that required it by a large lens at *d*. For transparent objects he applied a lens, as shown at *e*. Its convergent beam is reflected on the object placed at the end of the wire *ah*, by means of a small diagonal mirror in the axis of the tube, and inclined to this axis 45°. By this means a very strong light may be thrown through and past the object. By means of movable caps to cover the opening *abc*, and the lens *e*, all interference of foreign light is prevented; and without altering the position of the object, both methods of illumination may be successively adopted. Mr Potter attaches his objects to thin brass wires *a*, stuck into wooden handles *h*, and these pins pass through a slit cut into a small piece of cork attached to the sliding-piece *g*, which at the same time carries the lens *e* and the plane mirror, the whole of which are moved by the small arm connected to the crank, as at *i*. The adjustment of the object to the focus of the mirror is effected by turning a nut attached to the pivot on which the crank is fixed.

In the microscope used by Mr Potter he employs a speculum 1 inch in diameter, with a focal length of $1\frac{1}{2}$ inch; and he generally makes the distance between the object and the image from 12 to 14 inches.

The size of the speculum allows him to place an insect or other object of $\frac{1}{4}$th of an inch square in the tube, without any perceptible bad effect resulting from it.

When Mr Potter had adjusted the illuminators in the manner which we shall afterwards have occasion to describe, he "saw quite easily what are called the diagonal lines on the scale from the wing of the white cabbage butterfly, which has been proposed as a difficult test-object by Dr Goring; and it is such a one as those who have only seen the stronger longitudinal striæ or scales from the wings of moths and butterflies have little idea of." Mr Potter was also able to resolve a delicate blue tissue in the web of a spider called the *Clubiona atrox*, into its component fibres.

The great size of speculum used by Mr Potter arises from his being able to give all specula a true ellipsoidal figure, so as to remove the spherical aberration.[1] We have in our possession two of Mr Potter's instruments, one of them with a *spherical* and the other with an *ellipsoidal* mirror. The quantity of light and the defining power of the latter are unusual in such instruments.

Amici's Reflecting Microscope.

Amici's reflecting microscope.

This instrument is shown in section in figure 72, where *a* is a small ellipsoidal speculum about 1 inch in diameter, and $2\frac{6}{10}$ths in focal length. The object is placed on a stage *mn*, below the tube of the microscope, and the rays which issue from it fall upon a small speculum *b* inclined 45° to the axis of the ellipsoidal speculum, in the same manner as if the object had been placed in the tube as far to the right hand of the small mirror as it is below it. An image of this object is of course formed in the other focus of the ellipsoidal speculum, and may be viewed by a single or double eye-piece, as in other compound miscroscopes. Professor Amici, however, uses a negative eye-piece, consisting of two plano-convex lenses A, B.

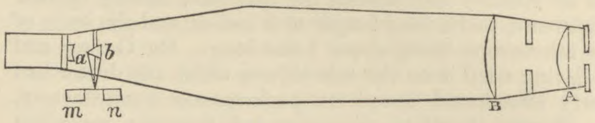

Fig. 72.

The new and peculiar part of this instrument is the use of the small speculum, which allows the object to be placed without the tube, and illuminated with the utmost facility.

Amici's Second Reflecting Microscope.

Amici's second reflecting microscope.

At the end of his Memoir, in the *Acts of the Italian Society*, on his first reflecting microscope, the author informs us that he had constructed another catadioptric one in 1813, which was more efficacious, and in which the aperture of the concave speculum was six lines, and its focal length eight lines, with an angular aperture of 44°. This form of the instrument is shown in the annexed figure, in which AB is the concave speculum, CD the plane speculum inclined 45° to the optic axis, and *m* a hole in its centre through which the rays from the object F pass to the speculum AB, from which they are converged upon CD and reflected to a focus at *f*, where they are received by the eye-piece at E. By polishing the speculum CD on the outside, opaque objects might be illuminated by the light which it may be made to reflect.

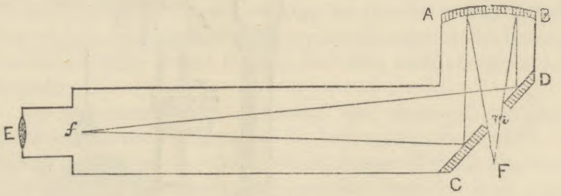

Fig. 73.

M. Vicenzo Amici, the son of the professor, has proposed to modify this construction, as shown in the annexed figure, where ABDC is a rectangular parallelopiped of glass, the curved surface of which, AB, is spherical or elliptical, and well polished and silvered. On the middle of CD a small cylinder of glass P is cemented with Canada balsam, the outer surface of which is concave, having its centre at F. The rays from the object at F enter the cylinder without refraction, and after reflection from AB and CD, as in the preceding figure, are conveyed to a focus at *f*, as in fig. 73.

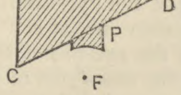

Fig. 74.

Another form of this instrument which we have seen, is shown in the annexed figure, where AB DC is a cylinder of

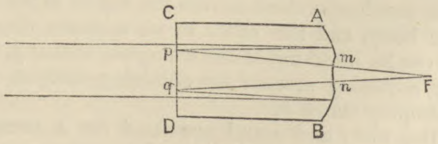

Fig. 75.

glass whose base AB is silvered, and has an unsilvered portion *mn* with its centre of concavity at F. The rays from the object at F pass without refraction to CD, part of which, *pq*, is silvered; and being reflected again from AB, they pass through the unsilvered portion Cp, Dq to their convergence as before at f, fig. 73, and enter the eye-piece E.

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[1] The process by which he does this is fully described in the *Edinburgh Journal of Science*, No. 12, p. 228, new series.

Dr Goring's Improved Reflecting Microscope of Amici.

Goring's improved reflecting microscope of Amici.

Mr Cuthbert, an ingenious London optician, constructed one of Amici's instruments, the speculum having $1\frac{1}{2}$ inch of aperture, and a focal length of 3 inches, and the body of the microscope being about 1 foot long. Dr Goring and he having tried it on the test-objects which the doctor had newly introduced, found its performance unsatisfactory. Dr Goring therefore recommended that the speculum should be only half an inch in focal length, and the body 4 or 5 inches long. Mr Cuthbert accordingly finished a pair of metals $\frac{6}{10}$ths of an inch in focal length, and only $\frac{3}{10}$ths in diameter. Their excellent performance induced Dr Goring and Mr Pritchard to turn their attention to the improvement of the instrument; and, as Mr Cuthbert[1] has been able to execute perfectly ellipsoidal metals, having an aperture equal to their sidereal focal length, or 54°, and of so small a diameter as $\frac{3}{10}$ths of an inch, they have produced an instrument of a superior kind.

This microscope is represented in fig. 76, where it is seen to rest on a tubular pillar, its body being held by a split socket. The pillar is screwed on a solid cruciform stand, to one of the legs of which an adjusting screw is applied, to produce steadiness. The body moves round a cradle-joint at the top of the pillar, and may be firmly fixed at any degree of inclination. The body of the microscope is shown at a, the eye-tube at d, and the eye-piece, which is a Huygenian one, at e. The focal lengths of the interior glasses of the eye-pieces, of which there are usually three, are $\frac{3}{4}$ths, $\frac{3}{8}$ths, and $\frac{3}{16}$ths of an inch. The tube containing the specula is shown at bc. The triangular bar which carries the illuminating reflector, the stage, and the apparatus for adjustment, is shown at f, and is soldered to the neck of the body. The mirror k is plane on one side, and has a plaster of Paris surface on the other. The stage l is a combination of rack and screw work, wrought by two concentric milled heads at m. The smallest of these moves the object in the direction of the body, and the other in an opposite direction. The stage can be lifted out of the triangular socket g, which carries the adjusting screw i for obtaining distinct vision, and the clamping screw h.

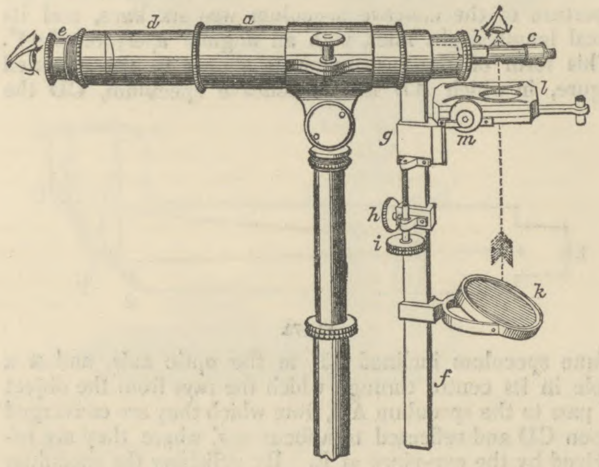

Fig. 76.

When the body and stand are used for a compound achromatic microscope, a tube containing the compound object-glasses below it, increasing in diameter from the object, is screwed into the body at b, in place of the tube bc. A rectangular prism, shown in dotted lines, reflects the pencils that pass through the object-glasses along the axis of the tube bc to the eye-piece e.

The following sets of metals are made for the reflecting microscope:—

No.	Solar Focus.	Angle of Aperture.	Distance between Object and side of the Tube.
1	2 inches.	$13\frac{3}{4}$°	$\frac{1}{2}$ inch.
2	1 „	$18\frac{1}{3}$	$\frac{1}{5}$ „
3	$\frac{6}{10}$ „	$27\frac{1}{2}$	$\frac{1}{10}$ „
4	$\frac{4}{10}$ „	$36\frac{1}{2}$	$\frac{1}{20}$ „
5	$\frac{3}{10}$ „	$41\frac{1}{4}$	almost 0 „
6	$\frac{3}{10}$ „	55	

The metals Nos. 1, 2, and 3 are those most useful for examining opaque objects. No. 3 is excellent also for all kinds of transparent objects. No. 5 can scarcely be used for opaque objects, as it leaves almost no space between the tube and the object for allowing the latter to be illuminated. No. 6 cannot be used at all for opaque objects, but is especially intended for the most difficult class of transparent test-objects.

Dr Smith's Reflecting Microscope.

Dr Smith's reflecting micro-scope.

Having constructed one of Sir Isaac Newton's microscopes in 1738, Dr Smith of Cambridge observed that the colours of objects were much more beautiful and natural than in refracting microscopes. He found that objects were very distinct and sufficiently light when the microscope had the following dimensions:—

Focal length of the speculum	$2\frac{1}{3}$	inches.
Diameter of ditto	1	„
Focal length of the plano-convex eye-glass	$2\frac{1}{3}$	„
Ratio of the distance of the object from the focus of the speculum to the focal distance of the speculum	1 to 19	„

Finding that, in order to obtain a high magnifying power, the speculum required to be very concave and small, he contrived another microscope with two reflecting spherical surfaces of any size, but so related to each other that the second reflection should correct the aberration of the first.

Dr Smith's microscope is shown in fig. 77, where AA is a concave spherical speculum, having its polished surface inwards. The rays from an object o placed in the slider mn will be reflected from the concave speculum AA upon the convex CC, and will have a distinct and magnified image of it formed before the convex eye-glass E, by which it will be magnified still more. This instrument, in short, is nothing more than the Cassegrainian telescope converted into a microscope, with this difference only, that in the telescope distinct vision is obtained by moving the convex mirror, whereas in the microscope it is obtained by a motion of the eye-glass. Dr Smith constructed one of these microscopes, which he found to perform "nearly as well in all respects as the very best refracting micro-

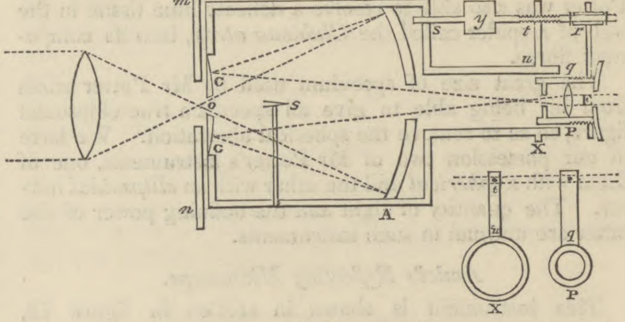

Fig. 77.

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[1] The process by which Mr Cuthbert was able to accomplish this difficult task is similar to that by which he gave truly hyperbolic figures to the mirrors of small Gregorian telescopes, with three inches of aperture and five inches of focal length.

scopes;" and the writer of this article has one of them now before him, which performs wonderfully well, though both the specula have their polish considerably injured. It shows the lines on some of the test-objects with very considerable sharpness.

The following are the dimensions, &c., of Dr Smith's reflecting mirror, as given by himself:—

Focal length of both specula	1·0000
Distance of the centres of both specula	1·6558
Distance of the image from the centre of the concave speculum	1·1337
Focal length of the eye-glass	0·1407
Distance of the eye behind the eye-glass	0·1479
Diameter of the eye-hole	0·0190
Distance of the object from the centre of the convex speculum	0·0626
Length of the concave speculum	15° 49′
Arch of the convex speculum	4° 50′ 49″
Distance of the stop *s* from the object	0·4545
Diameter of the stop *s*	0·038
Diameter of the hole in the concave speculum	0·143
Diameter of the hole in the convex speculum	0·049
Magnifying power, the focal length, &c., of the eye being 8 inches	300 times.

The dimensions of the instrument in our possession is very different:—

Diameter of the concave speculum	2·17	inches.
Focal length	2·17	"
Diameter of the hole in it	0·376	"
Diameter of the convex speculum	1·03	"
Diameter of hole in it	0·10	"
Diameter of stop	0·13	"
Distance of stop from hole in convex speculum	0·67	"
Distance of specula	3·80	"
Focal length of doubly-convex eye-glass	0·17	"

Sir David Brewster's Reflecting Microscope.

Sir David Brewster's reflecting microscope.

Notwithstanding the excellence of Professor Amici's microscope, we are convinced that it is not the peculiarity in its construction which constitutes it a different instrument from Newton's. This peculiarity is a disadvantage, and we consider the instrument as recommended solely by its possessing an ellipsoidal speculum with a large angle of aperture. The only advantage which can be ascribed to the instrument is a more convenient mode of illumination; but this advantage, whatever be its amount, is purchased at great sacrifices. 1. The whole instrument is an awkward-looking piece of mechanism, with its triangular bar and all its appendages. 2. It cannot be used in the vertical position, which we consider a defect. 3. By the use of the small reflecting speculum, *one-half of the whole light is lost.* 4. With small concave specula, such as those $\frac{3}{10}$ths of an inch in diameter, opaque objects cannot be illuminated.

The construction which has been proposed by Sir David Brewster to remedy most of these defects is shown in the annexed figure, where ABCE is the body of the instrument, which screws at its lower end C into the horizontal projecting arm DE of the stand, either of the achromatic microscope or the single microscope; so that we get rid of all trouble about the objects placed at *mn*, and their mode of illumination, as everything concerning them is the same as in other microscopes. This is certainly a great advantage; for neither naturalists nor amateurs are disposed to purchase and use two sets of the extensive apparatus necessary for holding, moving, and illuminating microscopic objects. At the lower end C of the body, where the object-glasses of the common compound microscope and the achromatic object-lenses are placed, is a small tube *abcd*, at the lower end of which is fixed the concave speculum *cd*, perforated with a very small hole at its centre, and with its concave surface upwards. Above it is the plane speculum *s*, fixed by a slender arm to the side *bd* of the small tube, and having its diameter a little greater than the perforation in the speculum *cd*. This little tube *abcd* screws into the arm DE, as if it were a microscopic doublet or single lens; and the body ABC may either screw upon the outside of this tube, or, what is better, upon a stronger piece of tube forming part of the arm DE. A concave illuminating reflector *kh*, for opaque objects, may screw on the back of the speculum *cd*, or the speculum itself may be made thick, and ground and polished on both sides, so that while one side illuminates the objects, the other magnifies them.

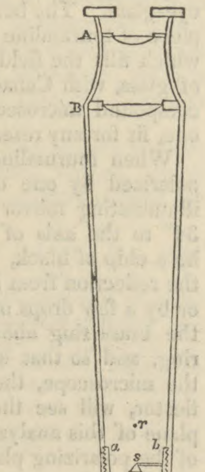

Fig. 78.

It is obvious that rays proceeding from an object at *mn* will be reflected from the plane speculum *s*, upon the concave speculum *cd*, exactly as if the objects were placed at *r*, as far above *s* as *mn* is below it, and an image of it would be formed in the other focus of the ellipsoid, *r* being the one focus, if the rays were not intercepted by the eye-piece AB, by which the image is farther magnified. By this mode of construction, the whole of the reflecting microscope, in place of having a separate stand and separate apparatus costing a large sum of money, is comprehended in the little tube *abcd*, and may be considered as a reflecting object-speculum, forming part of a general microscope, furnished with single lenses, doublets, and compound achromatics.

By the means now described are removed all the defects which we enumerated as belonging to Amici's combination, except the *third*, which is one of such importance that it is of consequence to consider how far it is capable of being remedied. Sir David Brewster has proposed to get rid of this loss of light by placing the object *mn*, as in Amici's instrument, outside of the tube, but inclined to its axis, and refracting its rays upon the speculum *cd*, by means of an achromatic prism *e*, in a manner analogous to his method of producing a similar effect in the Newtonian telescope.[1] The faces of this prism are equally inclined to the axis of the microscope and the axis of the pencil issuing from the point of the object under examination. As the prisms of plate and flint glass which compose *e* are cemented by a substance of nearly the same refractive power, there will be no farther loss of light than what is reflected at the two surfaces. A socket may be placed at D for holding an illuminating lens, or any other apparatus for opaque objects. But in order to avoid the incumbrance and expense of separate stands and apparatus for this as well as Amici's form of the instrument, we would propose that a strong piece of tube should be inserted in the opening, above *mn*, to screw into the upper side of the projecting arm, as shown in fig. 78; or a solid screw attached to the upper side of the tube, a little to the right hand of C, and above the opening, might screw into the lower end of the projecting arm DE. In these cases the object at *mn* will be placed on the ordinary stage, and illuminated in the common manner; but it will

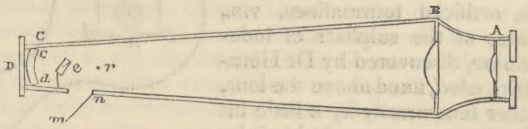

Fig. 79.

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[1] *Treatise on Optics*, edit. 1853, p. 494. (See also article OPTICS.)

be necessary to have a counterpoise at D, to balance the weight of the body ABC.

Those who are acquainted with the principle of the Cassegrainian telescope, and of Dr Smith's compound microscope, will readily see that the reflecting microscope, with the perforated speculum, may be converted into a more compound reflector, analogous to Dr Smith's, by making the little speculum *s* (fig. 78) convex, the figures of *d* and *s* being made hyperboloids.

CHAPTER IV.

ON POLARIZING MICROSCOPES.

Polarizing microscopes.

The use of polarizing microscopes is to observe and exhibit structures and phenomena which are invisible with the common microscope.

These microscopes were first used by Sir David Brewster, upwards of forty years ago, in his experiments on the structure of *Apophyllite*, *Amethyst*, and *Analcime*, and other mineral bodies; and also in his examination of various animal and vegetable organizations. In employing the single microscope for these purposes, he cemented plates of agate and tourmaline with Canada balsam to the plane side of a plano-convex lens,[1] and thus analyzed the polarized light, by means of which the peculiar structure was rendered visible. In other cases he preferred for the analyzer an achromatized prism of calcareous spar, in which one of the images only was visible,[2] or one in which he had extinguished one of the images by a particular process,[3] which he has described.

When considerable magnifying power was necessary, or when the structure was to be drawn by an artist, he used the compound microscope, in which the light was polarized and analyzed by various means, accommodated to the nature of the structure to be examined.

Single Polarizing Microscope.

Single polarizing microscope.

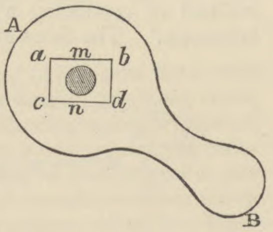

Fig. 80.

The simplest and most useful polarizing microscope is a hand one, such as AB, containing a convex lens *mn*. It is to be held in the right hand, as in fig. 80, and a plate of light reddish-brown tourmaline (or of the artificial tourmalines, viz., plates of the sulphate of iodoquinine, discovered by Dr Herapath), *abcd*, fixed above the lens, either temporarily by a little bit of soft wax, or cemented to it by Canada balsam. The last method has the advantage of preventing the loss of light by reflection from the first surface of the tourmaline, and removing any imperfection of polish that it may have. It would be advisable, indeed, to construct the microscope with two plano-convex lenses, and to place the tourmaline between them, joining it to both by Canada balsam, so that there would be no loss of light or imperfection of vision produced by the surfaces of the tourmaline.

The position of the plate *abcd* should be such, that when it is held as in the figure, the polarized light, which is to illuminate the object, should be unable to pass through it. This polarized light may be obtained either from light reflected at an angle of 56° from a plate of black glass, or from a bundle of plates of crown or flint glass, or mica (properly placed), or by transmission through a bundle of such plates, or from one of the images of a rhomb of calcareous spar.

When this light is obtained, the observer holds the microscope AB in his right hand, and examines through it the object in his left hand, turning AB slightly round, so as to bring it into the position in which it refuses to transmit any of the polarized light which passes through the object, and towards which, of course, the observer's eye is directed. When this is done, the peculiar structure of the object will depolarize or alter the polarization of part of the incident light; and this light, being no longer polarized, will pass through the plate of tourmaline to the eye, and exhibit on a dark ground, and in luminous and often beautifully coloured lines, the structure of the body.

If the body is transparent, and not flat, it may be advantageously placed in a little glass trough containing water or oil, or a fluid of the same refracting power as the body, so that the polarized light may be made to pass through it in all directions, and exhibit its entire structure.[1]

When the shape and surface of the body present no difficulties, the best method is to stick it by a transparent cement, or simply to place it upon a plate of tourmaline held in the left hand. The observer thus carries the polarizer and the object in his left hand, and in his right the magnifier and the analyzer.

When a second plate of tourmaline is not at hand, the object may be placed upon a rhomb of calcareous spar, above one of the images which that rhomb forms of a circular aperture on its lower or farther side, the light of the other image being stopped out by a piece of wafer.

When a small lens is needed, and strong light can be commanded, the magnifier and the analyzer may be united in one by making the magnifying lens of tourmaline.

When microscopic doublets or triplets are used, the plate of tourmaline may be placed between two of the lenses, and cemented to the plane side of any of the plano-convex lenses.

Compound Polarizing Microscope.

Compound polarizing microscope.

The simplest form of the compound polarizing microscope is to make the eye-glass into an analyzer, in any of the ways described for a single lens, the proper position of the plate of tourmaline being readily found by the motion of unscrewing the eye-glass. The polarizer is also a plate of tourmaline, laid on the slider-holder, and having the object laid upon its upper surface. If the polarizer is laid down in any accidental position, the proper position of the analyzer will be found by a slight unscrewing of the eye-glass. The best method is to place the small polarizing piece of tourmaline (which need not be larger than an object which fills the field of the microscope) between two pieces of glass, with Canada balsam interspersed. In this way a compound microscope may be converted into a polarizing one, fit for any researches, at the expense of a few shillings.

When tourmaline cannot be obtained, the light may be polarized by one or more plates of glass, placed on the illuminating mirror so that their surface may be inclined 34° to the axis of the microscope, and the analyzer may be a chip of black, blue, or any other kind of glass, having the reflection from its second surface removed by grinding, or by a few drops of black wax. If this chip is placed on the brass ring above the eye-glass so as to turn with that ring, and so that its surface is inclined 34° to the axis of the microscope, the observer, by looking into a little reflector, will see the object under examination when the plane of this analyzing plate is at right angles to the plane of the polarizing plate.

When the compound microscope is fitted up with Nicol's prisms,[1] and for the express purpose of exhibiting structures by polarized light,—which we believe was first done by Henry Fox Talbot, Esq.,—one of these prisms is fixed between the illuminating mirror and the slider-holder, to polarize the light, and another similar prism is placed above the eye-glass to analyze it. The last prism, however, is very inconvenient, as it contracts unpleasantly the field of view; and it is therefore necessary to substitute for it a plate of tourmaline, as already described; or, what is much better, as Sir David Brewster suggested, is to screw the analyzer into the lower end of the body of the microscope, immediately behind the object-glass.

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[1] *Edinburgh Transactions*, vol. ix., p. 141, note.

[2] *Ibid.*, vol. viii., p. 371.

[3] *Ibid.*, vol. ix., p. 141, note.

[1] It was in this way, by cementing fragments of crystals of analcime to a piece of wood, and holding the mineral in a small trough of almond oil, that Sir David Brewster detected the extraordinary structure of that substance.

The expense of constructing a Nicol's prism, the difficulty of making the one next the eye perfectly colourless, and the risk of a change taking place in the cement which unites the two parts of it, renders it desirable to have a simple, a cheap, and a durable substitute for it. The polarizer which has been employed by Sir David Brewster in his experiments on elliptical polarization, and on the action of crystallized surfaces upon light, where tourmaline could not be used owing to its colour, was a single rhomb of calcareous spar, with its natural surfaces, having thin plates of colourless glass cemented to them by Canada balsam, which removes any imperfection of surface, and at the same time protects the surfaces from any accidental injury, or from the deterioration of the polish, which arises from frequently cleaning them. This rhomb ABCD had a circular aperture *a*, placed upon its lower surface, and of such a diameter that it just separated the two images *b*, *c*, seen from above. This rhomb may be placed either beneath the slider-holder or upon it, and by sticking a piece of wafer upon any one of the images *b*, *c*, and leaving the other exposed, and placed exactly beneath the aperture of the object-glass, we have the most perfect polarizer that can be constructed. The object to be examined may, if necessary, be laid above the circle *b*.

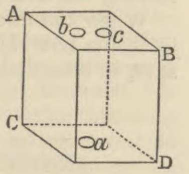

Fig. 81.

By this construction of the polarizer we obtain another advantage; we may so adjust the size and distance of the pencils *b*, *c* that both of them may be included in the field of view, and by placing one of the objects to be examined above *b*, and another of the same above *c*, we may observe them at the same instant under their opposite colours, if the depolarized light is coloured, which it generally is.[2]

These rhombs may be made even out of rhombs crossed with veins, which multiply the images, because the multiplied images are at too great a distance from the principal ones to be visible. This is a peculiar advantage, as it is often very difficult to get good pieces of spar free from this composite structure.

This method of constructing a polarizing rhomb enables us to take advantage of the two lateral images, which accompany the two principal images in crystals crossed by one vein. These lateral images, shown at *m*, *n*, are distant from one another, and from the principal images *b*, *c*; and as each of them consists of light wholly polarized in one plane, we have only to bring one of them under the aperture of the object-glass to have an admirable polarizer, without being at the trouble of stopping out any of the other pencils.

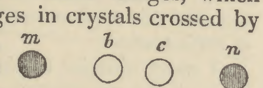

Fig. 82.

The images *m*, *n* are much less bright than the principal ones *b*, *c*; but this is really of no consequence, as we can obtain any degree of light we choose in the microscope, either by the condensation of artificial, or the use of solar light.

When the vein by which these lateral images are formed is above a certain thickness, their light is white; but they are most frequently coloured; and the observer who understands the cause of these colours may make this coloured pencil of great service in microscopical observations. If he uses a rhomb which gives to *m* a green of the second order, it will contain none of the extreme violet and blue rays, and none of the extreme red; so that it affords a more homogeneous pencil than if it were white light, and thus improves the performance of a microscope that is not achromatic.

He may in like manner use tints which give the red extremity or the blue extremity of the spectrum, or, even when the tint is divisible by the prism into periodical bands, he may absorb the least luminous of these bands, and create a homogeneous pencil of polarized light of inestimable value, in particular researches and with particular microscopes.

But, independent of these advantages, the method of using a lateral pencil *m* has the great advantage of not requiring much thickness in the rhomb. A Nicol's prism, and a rhomb in which the two principal images *b*, *c* are used, must be about an inch thick in order to be efficacious; but the distances *mn* or *mb* are the same at all thicknesses, so that we can use rhombs for this purpose which are quite useless for any other.

It is scarcely necessary to add, that similar rhombs in which either the principal images *b*, *c*, or the lateral ones *m*, *n*, are used, may also be employed for the analyzer. For this purpose a thin plate, in which *m* or *n* is white, is peculiarly applicable, as it enables us to see at once the whole field of the microscope.[1]

CHAPTER V.

ON SOLAR AND OXYHYDROGEN MICROSCOPES.

Solar and oxyhydrogen microscopes.

The solar microscope is a well-known popular instrument, for exhibiting on a white screen, in a dark chamber, magnified images of minute objects, illuminated by the condensed light of the sun. As the sun cannot often be commanded in our climate, this instrument may be considered as having fallen into disuse: but the discovery of the lime-ball light by Mr Drummond amply supplies the place of the great luminary, in so far as the microscope is concerned. The instrument has accordingly been revived under the name of the oxyhydrogen microscope, and is now a favourite public exhibition.

The solar microscope was proposed by Dr Lieberkhun in 1738; and early in 1739, when he paid a visit to London, he exhibited an instrument of his own construction to several members of the Royal Society, and to Mr Cuff, Mr Adams, and other London opticians.

This microscope is nothing more than a convex lens, in front of which, a little farther from it than its principal focus, is placed a microscopic object, the rays of the sun being reflected in a horizontal line, and condensed by a lens. This will be understood from figure 83, where CD is the convex lens, E the object placed before it, and AB the illuminating condenser. An enlarged image of E will be formed on the right hand of CD, upon a wall or screen, and the size of the enlarged image will be to that of the object as the distance of CD from the screen or wall is to CE, the distance of the object from the lens. Dr

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[1] This ingenious prism, consisting of two pieces of calcareous spar cemented together so as to transmit only one image, derives its name from its inventor, the late William Nicol, Esq., of Edinburgh, and is of great use in all experiments on the polarization of light, particularly where the colour of tourmaline would interfere with the phenomena to be observed.

[2] The most interesting objects for the polarizing microscope are minute crystallizations of all kinds, but particularly composite minerals, such as apophyllite, amethyst, analcime, and a large class of crystals to which the name of "circular" has been given, and an account of which will be found in a paper in the *Edinburgh Transactions*, vol. xx., p. 60, 1853.

[1] We have recently (May 1857) seen these methods of using rhombs in place of Nicol's prisms successfully adopted by Professor Amici in his achromatic microscopes, and we are satisfied that those who have once employed them, either for the purposes of research or amusement, will never use any other pieces of apparatus.

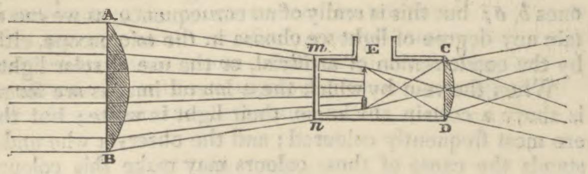

Fig. 83.

Lieberkhun's solar microscope had no mirror for reflecting the sun's rays into the tube, so that it could only be used for a few hours, when the tube could be conveniently pointed to the sun. The improvement of adding a mirror was made by Mr Cuff, who constructed the instrument in a very superior manner.[1] Dr Lieberkhun subsequently fitted up the solar microscope to show opaque objects; but the method which he employed is not known. Since the time of Mr Cuff the solar microscope has undergone many improvements. Mr Benjamin Martin added greatly to the value of this instrument by fitting it up both for opaque and transparent objects, in the manner shown in figs. 84 and 85. In fig. 84 it is shown as fitted up for opaque objects. The body ABCDEF has the part ABCD of a conical, and the part CDEF of a tubular form. A large convex lens, corresponding with AB in fig. 83, is placed at AB, at the end of the conical tube ABCD, which screws into the square plate QR, which is fastened to a window-shutter opposite a hole of at least the size of the lens AB, by means of the screws *e, d.* Upon the square plate QR there is a movable circular plate *abc.* To this circular plate is attached the silvered glass mirror NOP, placed in a brass frame, which moves round a joint PP, and which may be placed in any position with regard to the sun, so as to reflect his rays into the tube ABCD by means of rackwork and pinions at Q and R. The pinion Q moves the circular plate *abc* (to which the mirror NOP is fixed) in a plane perpendicular to the horizon, while the nut R gives it a motion in an opposite plane. The light introduced by this mirror falls upon the lens AB, which throws it in a condensed state upon any object in the tube. But before it reaches the opaque object it is received by a mirror M, placed in the box HILX, which reflects the condensed light back upon the face of the object E (fig. 83) next to the lens CD. This mirror is adjusted to a proper angle by the screw S.

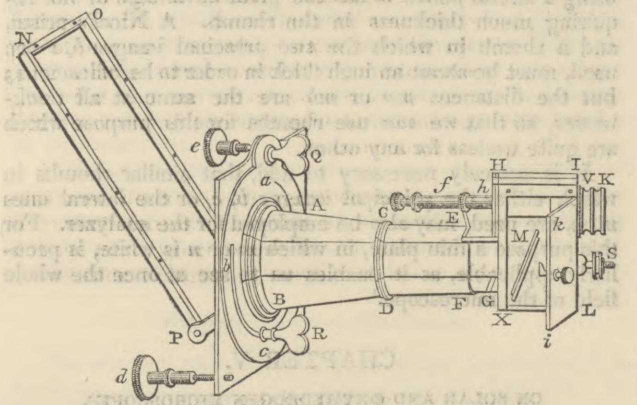

Fig. 84.

Above the body ABEF is seen the part *f* VK, which carries the sliders or objects, and the object-glass or lens CD (fig. 83). The tube K slides within the tube V, and V again slides into the box HILX. These tubes carry each a magnifying lens. The inner tube K is sometimes taken out of the other V, seen within the box, and used alone. The sliders and objects are introduced into a slit or opening at H. The brass plate to the left of H is fixed to a tube *h*, by means of a spiral wire within the tube, which presses the plate against the side of the box HILX, so that the sliders, when placed in the opening, are pressed against the side of the box.

In using this microscope, the sun's rays are first made to pass along the tube ABCD by the nuts Q and R. The box for opaque objects, HILX, is then slid by its tube G into the tube EF. The slider containing the object, having its face to be examined turned to the right hand, is then pushed into the opening at H, till the object is in the centre of the tubes V, K. The condensed light falling upon the mirror M is then thrown back on the face of the object of the slider, and the door *ki* shut. Upon a white paper screen or cloth, from 4 to 8 feet square, and placed at the distance of from 6 to 10 feet from the window, the observer, in the room made thoroughly dark, will see on the screen a magnified representation of the object, which may be rendered distinct at different distances of the screen, by pulling out or pushing in the tubes V, K containing the convex lenses. As the sun is constantly moving, its rays must be kept in the axis of the tubes by now and then turning the nuts Q and R.

When the microscope is to be used for transparent objects, the box HILX, with its tube G and other appendages, is removed, and the apparatus shown in fig. 85 substituted for it. This is done by sliding the tube Y of fig. 85 into the tube EF of fig. 84. A slider containing the magnifying lens is then slipped through the opening at *n*, and a second condenser may or may not be inserted in the opening at *h*. The slider with the object is then placed in the opening *m*, and when its magnified picture falls upon the screen, it is adjusted to distinctness by turning the milled nut O.

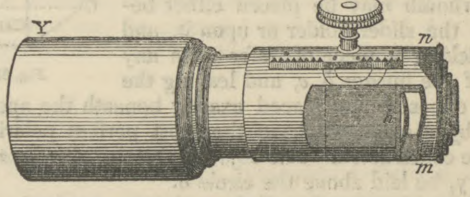

Fig. 85.

The picture formed by a solar microscope being in Dr Robison's opinion "generally so indistinct that it is fit only for amusing ladies," he proposed to use as an object-glass the achromatic eye-piece of four lenses, constructed by Mr Ramsden for telescopes. Having made the experiment, he found the image "perfectly sharp," and recommended this application "to the artists, as a valuable article of their trade."

New solar microscope.

A much simpler method, however, of correcting the defects of the microscope, is to use compound achromatic lenses, which were first suggested by Mr Benjamin Martin.

Another mode of improving the instrument was proposed in 1812 by Sir David Brewster,[1] who has described a new solar microscope which can be rendered achromatic. The method of doing this is shown in the diagram (fig. 83), where AB is the condensing lens, and CD the object-glass, cemented firmly into one end of a tube *m*CD*n*, which has a tubular opening at E, while the other end of the tube has a circular piece of parallel glass cemented upon it. The tube *m*CD*n* is then filled with water, or any other fluid; and the object, when placed upon a slider or held in a pair of forceps, is introduced at the opening E into the fluid. The mechanism for producing these effects is easily conceived. By the instrument thus constructed, imperfectly opaque and corrugated objects, rendered transparent, and extended by the fluid medium, may be examined in this microscope, though incapable of being used in any other. Objects may be even dissected in the aqueous tube. Nay, objects preserved in spirits might be exhibited by immersing the bottle, if it is small, in the trough or tube *m*CD*n*.[1]

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[1] See Baker *On the Microscope*, vol. i., p. 22.

[1] *Treatise on New Philosophical Instruments*, p. 410.

But the most important purpose effected by this form of the instrument is, that it can be rendered perfectly achromatic by using a fluid of higher dispersive power than the glass lens CD, and making the interior curvature of the side CD, which touches the fluid, of that degree of convexity which will convert the fluid into a concave lens capable of correcting the colour of CD. The lens CD may be made most advantageously of fluor spar, which, from its low dispersive power, might form an achromatic combination with water.

Reflecting solar microscope.

Although, in so far as we know, metallic specula have never been regularly fitted up as a reflecting solar microscope for use, yet every person familiar with, and in the habit of using specula and lenses, must have made the experiment of forming magnified images both in solar and artificial light, with small concave specula. The perfection of these images cannot be doubted; and it has often appeared to us surprising that the optician did not avail himself of such a combination for a solar microscope. Neither the Newtonian nor the Amician form of the instrument offers facilities for this purpose. Sir David Brewster has therefore proposed to employ his form of the reflecting microscope for a solar and oxyhydrogen instrument. Its facilities for this purpose are very great, and there can be little doubt that it will be practically successful, and will be as superior to other solar microscopes as the best reflecting compound microscope is to the ordinary compound microscopes. Dr Goring made an experiment with the Amician microscope; but he obviously considers it as not likely to succeed, remarking, that "after all that could be done, a refractor would be sure to beat it hollow; therefore," says he, "I shall take my leave of the subject, as I cannot conscientiously recommend such an instrument."[2] It is no wonder that this experiment failed, because Dr Goring seems to have used *the whole of the Amician microscope*, eye-glasses and all, as the magnifier in the solar microscope, and therefore it could not be considered as a *reflecting* solar microscope, being in fact as much a *refracting* one. The construction to which we have above referred is shown in the annexed figure, where AB is the illuminating lens, throwing the condensed rays of the sun upon a transparent object *mn*. The rays from this object falling upon the small speculum *e*, are reflected to the deep concave speculum *cd*, so placed that the image is formed at MN on a screen at some distance behind it, distinct vision being obtained either by moving the object or the speculum.

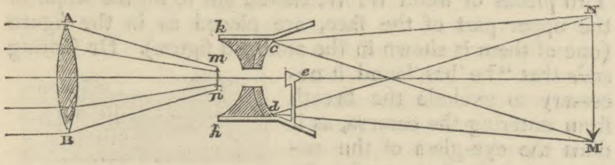

Fig. 86.

For opaque objects this form of the instrument is peculiarly adapted. The parallel rays of the sun falling upon the deep speculum *kh*, are condensed by it and thrown on the inner face of the object *mn*, of which a magnified image is formed, as before, at MN. A greater condensation of light may be obtained by using the lens AB, so that the speculum *kh* shall receive its convergent beam before the rays reach their focus and complete their convergency.

In this construction we have the disadvantage of two reflections, belonging also to the Amician form; but this may be considered as compensated by the image being without the tube, and more under our command. Though this is true in the compound microscope, yet the advantage of having the object outside the tube is of less consequence in a solar microscope. To avoid therefore two reflections, and two mirrors with their relative adjustments, Sir David Brewster has proposed to construct the reflecting solar microscope in the manner shown in the annexed figure, where *cd* is the perforated concave speculum, *mn* the object in one of its foci, and MN the magnified image in its other focus. The object *mn*, placed on a slider passing through an opening in front of the speculum, is illuminated as an opaque object by the lens AB, whose refracted rays are farther condensed by a lens placed in the aperture of the speculum. This form of the solar microscope is therefore singularly adapted for opaque objects; and as the whole of the effect of the instrument is produced by a single reflection from a single surface, it is the simplest optical instrument in existence. In order to throw light upon *mn* as a transparent object, the rays must pass through it in an opposite direction from the side MN, and this may be done by the very same method given by Mr Potter, and represented in fig. 71.

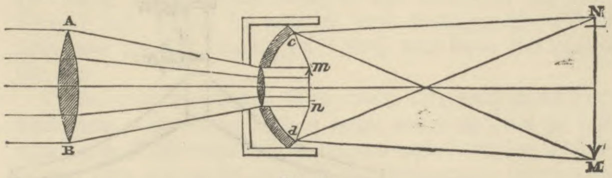

Fig. 87.

The simplicity and practical value of this instrument will be immediately recognised by comparing it with the complex opaque box, which in all solar microscopes is a necessary appendage for opaque objects. See fig. 84.

Dr Goring's Solar Camera Microscope.

Dr Goring's solar camera microscope.

Dr Goring has described in the *Micrographia* a very complete solar microscope, which has the property of exhibiting the image on a horizontal curved surface, placed in a darkened camera, at which two or more persons can look at the same time. It is, to a certain extent, a new instrument, but can also be used like the common solar microscope in a darkened room.[1]

This instrument, with all its parts, is shown in figs. 88, 89, 90, and 91; fig. 88 being a geometrical elevation of the instrument, *one-tenth* of the real size, the various parts being represented as if formed of transparent matter. A strong framework A of wood rests upon four legs, having a large hole in it, into which the instrument is fixed with two

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[1] See *Treatise on New Philosophical Instruments*, p. 401, for an account of the advantages of examining objects immersed in fluids.

[2] Dr Goring states that a friend of his had constructed a solar microscope with metals on the Amician principle, and without a body or eye-glass, which exhibited a variety of test objects in a highly satisfactory manner.

[1] Dr Goring calls this instrument a "solar engiscope," while he gives the name of "solar microscope" to the *same* instrument when used in a dark room in the common way. The introduction of the image into a camera becomes thus the reason for changing a *microscope* into an *engiscope!* The word *engiscope*, however appropriate it may be as a companion to the word *telescope*, is quite inapplicable to any kind of solar microscope.

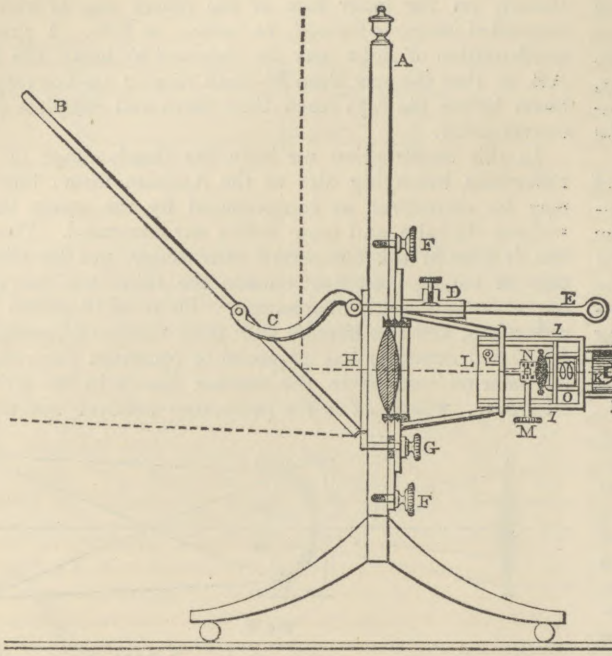

Fig. 88.

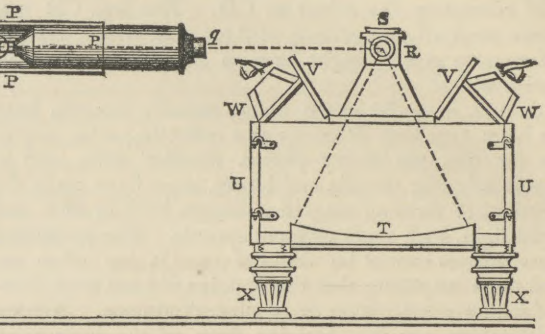

Fig. 89.

screws FF. The frame is large enough to protect the observer from the solar rays. A long plane mirror B is fixed to an arm C, which moves round a pin fixed to the side of the mirror frame, and also round a joint attached to a strong round wire E, which slides backwards and forwards in the tube D, having a spring within, and a pinching nut to fix it in its place. The inclination of the mirror is varied by pulling out or pushing in the wire E; and another motion of the mirror is produced by the action of the milled head G on a rack and pinion. A common illuminating lens, five inches in diameter and one foot in focal length, is placed at H. Dr Goring recommends an achromatic lens[1] (which would be a very expensive appendage), though he says that he has never used one. The main body of the microscope is conical, having a bayonet catch at L to receive the rest of the instrument, viz., the tube carrying the stage and rackwork. This tube 1 1 moves within the conical one by means of the milled head M and rack and pinion N. The end of this tube is closed, and an ordinary slider-holder O is fixed to it. On the inner side of the stage, near N, is fixed a condensing lens, about one and a half inch in diameter and two inches in focal length, which, by means of a sliding wire passed through a hole in the stage, can be moved from one side of the tube to the other, and also made to approach to or recede from the stage. A second tube PPP (fig. 90), slit open at the sides, is screwed into the tube in which the stage moves; and into this tube the optical part *q* is made to slide, the object-glass being placed at K. Dr Goring here remarks that "the focus may of course be roughly adjusted, by sliding the body backwards and forwards in its containing tube, before it is attached to the camera, fig. 89; but when this has been done, it must of course remain immovable. I look upon it," he continues, "as a *principle* in the solar microscope, *that the magnifier or object-glass should not be moved, but always remain at a fixed distance from the illuminator.*" Perhaps we do not distinctly understand the import of this passage; but we apprehend that the magnifier or object-glass may be, nay, must be, moved in any way that is necessary to produce distinct vision upon the screen, whatever be its distance; and that the essential condition is, that the distance of the illuminator and the object shall be invariable, the object being, if possible, accurately situated in the focus, unless where a slight deviation is necessary to prevent its destruction by the concentrated heat of the solar rays.

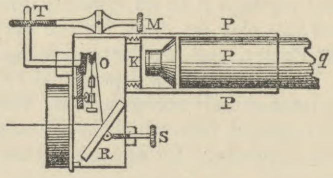

Fig. 90.

The end of the tube *q* is now pushed into another piece of tube at R, fig. 89, which communicates with a conical tube of brass, "having a rectangular prism, with its reflecting side silvered,[1] or a plane metal adjusted at its head S, so as to throw down the image to the bottom of the box or camera, where it is to be received on paper (at T), or on a surface of plaster of Paris duly curved to suit its shape." The camera WWXX is constructed with windows V, V, to permit two persons to view the picture on the table T. Two pieces of wood W, W, carved out to fill the slope of the upper part of the face, are placed as in the figure (one of them is shown in the annexed figure). Dr Goring adds that "he has found it necessary to exclude the breath from entering the camera, as it dims the eye-glass of the engiscope, and thus spoils the image;" but he does not mention whether this is the object of the pieces of carved wood, or whether they are used to keep extraneous light

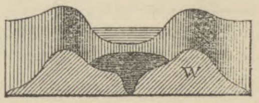

Fig. 91.

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[1] See *Edinburgh Journal of Science*, No. 9, new series, p. 85; and our chapter on the Illumination of Microscopic Objects.

[1] Dr Goring is surely mistaken in saying that the side of the prism should be *silvered*; for as *total reflection* commences at 41° 49' for glass, and takes place at all greater angles of incidence, the light incident at 45° will be totally reflected. But even if the least oblique part of the conical beam should penetrate the reflecting surface (which it cannot do), part of the picture would have the light of silvered reflection, and the other part the *double* light of total reflection, which would never answer. We would prefer a plane metallic speculum to the prism, even if sufficiently homogeneous not to affect the accuracy of the picture.

Micro-scope.

from the eye,[1] which, in so far as the figure indicates, does not appear to be the case.

The sides U, U of the camera may be removed at pleasure, to allow the observer to draw the picture on the table, the light being excluded by some black drapery, while the hand passes through a suitable opening in it. Dr Goring recommends that the whole of the interior of the conical brass tube and camera should be well blacked, or lined with black silk velvet.[2]

In applying this instrument to opaque objects, the opaque box, shown in fig. 90, is applied to the conical tube in fig. 76 by means of the bayonet catch at L. A plane mirror R, adjusted by the screw S, throws the light of the illuminator to the object O placed in the conjugate focus of the eye-glass K, by means of the milled nut M and screw T, which causes the stage and the object to approach to or recede from the lens K.[3] The stage is formed by a piece of cork covered with black velvet. PP is the tube into which the body *q* of the microscope is inserted, as in fig. 76.

This instrument may be converted into a common solar microscope by unscrewing and removing the tube PP, and placing a simple object-glass in an appropriate mounting at M. The whole apparatus is then removed from the frame A, and screwed to a window-shutter in the usual way.

On the Oxyhydrogen Microscope.

On the oxy-hydrogen micro-scope.

The great popularity of the public exhibitions made with this instrument has turned the attention of opticians and amateurs to its improvement. Mr Pritchard has written a long and interesting chapter of nearly fifty pages on the subject of solar and oxyhydrogen gas microscopes, in the *Micrographia*, already referred to, and has given a most popular and minute account of all the details of the instrument. These details, to which we must refer out readers, do not belong to an article like the present; and we shall content ourselves with explaining what an oxyhydrogen microscope is, and how the optical apparatus of a solar microscope may be readily converted into that of an oxyhydrogen one, and *vice versa*.

An oxyhydrogen gas microscope differs from a solar one chiefly in this, that a brilliant light obtained by igniting a ball of lime the size of a pea (hence called the *pea* or *lime* light, or more appropriately the *Drummond* light, from its inventor, the late Mr Drummond) with oxyhydrogen gas, is substituted in place of the solar rays. This enables us to enjoy the amusement of the solar microscope apparatus in all weathers and at all hours of the day.

As the lime-ball light, however, is at our elbow, it sends forth diverging rays; whereas the rays of the sun are parallel. A very beautiful principle, already referred to in our article Micrometer, enables us to give the simplest construction for this purpose. Let AB (fig. 92) be the illuminating lens of the common solar microscope, throwing the parallel rays *ef* of the sun upon the object *mn*, and let the whole instrument be in perfect adjustment; then, without moving or changing any part of it, we may convert it into an oxyhydrogen microscope, where the light diverges from the lime-ball L, simply by placing in front of AB another lens CD, whose focal length is equal to the distance of the lime-ball light L from the lens AB. The oxyhydrogen microscope will then have its objects at *mn* illuminated in precisely the same way as they were by the sun's rays. The two lenses CD, AB, should be in contact, the space in the figure being left only to show the parallel rays *ef*. Now, as L is the focus of the lens CD, the converging rays *ef* will be parallel, and consequently will be refracted by AB exactly as if they had been the rays of the sun.

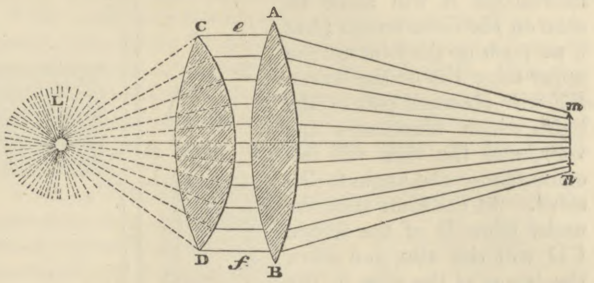

Fig. 92.

If the instrument had been made originally as an oxyhydrogen microscope, with a large and deep lens at AB, which would be required to refract rays diverging from L to *mn*, then we might convert the instrument into a solar microscope, by simply placing a *concave* lens in front of AB, whose focal distance is equal to the distance of L from AB. This concave lens will give such a divergency to the parallel rays of the sun that they will have their focus at *mn*.

Our readers will find the most ample details respecting the gas apparatus, and the method of managing and using the instrument, in Mr Pritchard's *Micrographia*.

Notwithstanding the precautions to prevent an explosion of the oxygen and hydrogen employed in this apparatus, we would recommend to Mr Pritchard, and those who may construct such instruments, to use a common oil or gas lamp supplied with oxygen gas, such as Sir David Brewster some years ago recommended as a safe substitute for the lime-ball light, when it was proposed to use the latter for lighthouses. This oxygen lamp, equally safe and brilliant, has been tried with success at the Trinity House, and will, we are confident, be soon in universal use, not only in lighthouses, but wherever strong lights are required.[1]

On the Apparatus for Dissolving Views.

On the apparatus for dissolving views.

By employing two microscopes similar to the oxyhydrogen microscope, but of a larger size, the interesting optical illusion of *dissolving views* is produced. In order to admit objects four or five inches square, condensing lenses 8 or 10 inches in diameter are necessary. The views to be employed are painted on glass with much more care and minuteness than those employed in the magic lanthorn. The following is the method of causing one picture to dissolve and pass gradually into another. The two microscopes are placed near each other, and at the distance of 20 or 30 feet from a white screen for receiving the images. The position of the microscopes is then adjusted so that each throws the image of the picture placed in it on the same part of the screen. When this is obtained the microscopes are fixed, and in front of them an apparatus like that in figure 93, where A and B are the front openings of the two microscopes, and CD and EF two dark screens moveable upon the centres *m*, *n*, and capable

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[1] In using this and all other optical instruments where perfect vision is either agreeable or essential, we would recommend the use of the Greenland snow spectacles, cut, to suit the individual, from a plaster of Paris cast of the eyes, nose, and brow.

[2] Mr Potter found black velvet to be superior to any other blacking for the interior of his reflecting microscope, and we have used it successfully in the solar telescope in observing the extreme red rays of the spectrum. (*Edin. Jour. of Science*, No. 11, p. 62, new series.)

[3] The illumination is here far too oblique. The mirror should be nearer P, and the screw MT should be made to move the object-glass K, in order that the focus of the illuminator may always fall on the object O.

[1] Mr Drummond heated the lime-ball with three flames of a spirit-of-wine lamp. It may be done even with one flame urged upon the ball by a blowpipe of oxygen gas.

Dissolving views.

of moving up and down on the vertical rod GH. These screens are fixed in front of the openings A, B, and close to them. In the position of the dark screens, shown in the figure, the view in the microscope A will alone be seen on the white screen; but if we push up the joint *mn* the upper edge E*m* of the screen EF will obstruct part of the light which illuminates the view, and the view will become fainter and begin to dissolve. At the same time the under edge D of the screen CD will rise also, and allow the image of the view in the microscope B to appear very faintly, and mixed up with the image of the other view on A. As EF rises, and causes the view in A to dissolve, CD will rise, and cause the view from B to be brighter and more distinct. By continuing the upward motion of *mn*, the view from A will gradually dissolve till it disappears altogether, while the view from B will gradually become more and more distinct till it obliterate the view from A. By causing *mn* to descend the reverse will take place, the view from B now dissolving till it is obliterated by that from A.

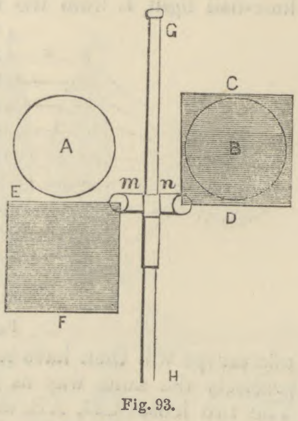

Fig. 93.

Simpler instrument for dissolving views.

Another very ingenious method of exhibiting dissolving views is to include *two* views in the same piece of paper, so that when you see the piece of paper by *reflected* light you see distinctly one of the views like an ordinary painting or engraving; but when you look through the paper you see the other view by *transmitted* light. This piece of paper is placed at the wide end of a conical tube, at the other end of which is a convex lens to magnify it. On the upper side of the wide end of the tube, a lid like that in the stereoscope opens and shuts, so that when open it throws light upon the face of the piece of paper containing the view to be seen by reflected light, and, when shut, the eye sees the picture to be seen by transmitted light. On the lower side of the wide end of the tube is another lid which opens and shuts. When shut it prevents the transmission of light, which would interfere with the view of the picture seen by reflected light. Now, the two lids are so connected by a wire that as one opens the other shuts, the one being completely open when the other is completely shut. By this means the picture seen by reflected light gradually dissolves till it is obliterated by a transmitted picture, and *vice versa*. The pictures for this apparatus are *circular*, and are very nicely executed by Parisian artists. A larger apparatus, which contains rectangular pictures about 8 inches by 6, has been constructed under the name of the Polyorama Pantoptique. A variety of natural effects, such as the motions of ships, &c., rainbows, fire, &c., may be produced by two, three, or more lanthorns. A trioptric lanthorn, in which one light is made to produce the effect of two or three lanthorns, has been described by Mr Beechey.[1] Microscopes are inserted in apertures at proper angles in the sides of the lanthorn, and three-sided prisms are used to reflect the rays to the screen. Photography now supplies us with beautiful drawings of all classes of objects for the instruments described in this chapter.

CHAPTER VI.

ON THE ILLUMINATION OF MICROSCOPIC OBJECTS.

On the illumination of microscopic objects.

The methods of illuminating microscopic objects that have been long in use have been described in the preceding chapters. They consist in throwing light upon the object, either by means of a mirror or a lens, or both combined; but the nature of the light employed, the magnitude of the pencil, its condition with regard to parallelism, divergency, or convergency, and the diameter of the pencil employed, or the direction in which it falls upon the object, have never been discussed as matters of science, although upon these the performance of the finest instrument essentially depends.

In so far as we know, the most important of these topics was pressed upon the notice of the scientific reader by Sir David Brewster, in the year 1820; and in order that the progress of improvement in this essential branch of the art of making discoveries with the microscope may be understood, we shall quote his observations on the subject:—

"The art of illuminating microscopic objects is not of less importance than that of preparing them for observation. No general rules can be given for adjusting the intensity of the illumination to the nature and character of the object to be examined; and it is only by a little practice that this art can be acquired. In general, however, it will be found that very transparent objects require a less degree of light than those that are less so; and that objects which reflect white light, or which throw it off from a number of lucid points, require a less degree of illumination than those whose surfaces have a feeble reflective force.

Rules for illuminating microscopic objects.

"The following rules may be laid down respecting the illumination of microscopic objects, and the method of viewing them:—

"1. The eye should be protected from all extraneous light, and should not receive any of the light which proceeds from the illuminating source, excepting that portion of it which is transmitted through or reflected from the object.

"2. Delicate microscopical observations should not be made when the fluid which lubricates the cornea of the observer's eye happens to be in a viscid state, which is frequently the case.[1]

"3. The figure of the cornea will be least injured by the lubricating fluid, either by collecting over any part of the cornea, or moving over it, when the observer is lying on his back, or standing vertically. When he is looking downwards, as into the compound vertical microscope, the fluid has a tendency to flow towards the pupil, and injure the distinctness of the vision.

"4. If the microscopic object is longitudinal, like a fine hair, or consists of longitudinal stripes, the direction of the lines or stripes should be towards the observer's body, in order that their form may be least injured by the descent of the lubricating fluid over the cornea.

"5. The field of view should be contracted, so as to exclude every part of the object excepting that which is under immediate examination.

"6. The light which is employed for the purpose of illuminating the object should have a small diameter. In the day time it should be a single hole in the window-shutter of a darkened room, and at night it should be an aperture placed before an Argand lamp.

"7. In all cases, and particularly when very high powers are requisite, the natural diameter of the light employed should be diminished, and its intensity increased by optical contrivances.

"8. When a strong light can be obtained, and indeed in almost every case, homogeneous light should be thrown upon the object. This may be done either by decomposing the light with a prism, or by transmitting it through a coloured glass, which has the property of admitting only homogeneous rays."

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[1] *Art Journal*, May 1850.

[2] See *Brande's Journal*, vol. ii., p. 127.

In the same article Sir David Brewster has described "a new method of illuminating objects in the solar and the lucernal microscopes." "The great defects," says he, "which still attach to the solar and lucernal microscopes, arise from the imperfect method of illuminating the objects. The method suggested by Æpinus, and employed almost universally by opticians, of reflecting the light concentrated by a lens upon the objects, by means of a plane mirror, is good enough as far as it goes; but in consequence of the light arriving from one direction only, the surface of the illuminated object is covered with deep shadows, and the intensity of illumination is by no means sufficient when the power of the instrument is considerable. We propose, therefore, that in the solar microscope the sun's light should be reflected by a very large mirror through four apertures, A, B, C, D (surrounding the tube T), each of which is furnished with an illuminating lens. The four cones, if condensed, are then received before they reach their focus, each by an inclined mirror, which reflects them upon the object; the distance of the lens from the mirror, added to the distance of the mirror from the object, being always less than the focal length of the illuminating lens. In the lucernal microscope it would be desirable to place an Argand lamp opposite each of the apertures A, B, C, D. By these means the light would *fall upon the surface of the object in four different directions;* a high degree of illumination would be obtained for very dark objects; and by *shutting up one or more of the four lenses, or parts of them, we shall be enabled to find the particular direction of the light which is best suited for developing the structure which it is the object of the observer to discover.*"[1] Although the focus of the illuminating rays should always fall upon the object, for the reasons already assigned, yet in the preceding method, applied to the solar microscope, a deviation from this rule becomes necessary, for *two* reasons:—1*st.* Because, if the focus of the illuminating lens fall exactly upon the object it might burn it, or destroy it by corrugation; and, 2*dly*, In the ordinary illuminating lenses, the diameter of the focal spot, or image of the sun, is not sufficient to cover the whole object, or to give a sufficient luminous field around it. For these reasons it is recommended in the preceding extract to place the object a little way within the focus of the illuminator, that is, between the illuminator and its focus. But if the object is such that it cannot be injured by the solar heat, and if the illuminator is sufficiently large to give a focal spot capable of filling the field of the microscope, then the object should be placed in the solar focus of the illuminator.

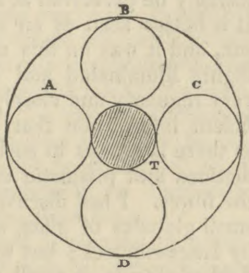

Fig. 94.

Oblique illumination.

Dr Wollaston's method of illumination.

After a lapse of nearly ten years, the subject of microscopic illumination was discussed by Dr Wollaston, in his paper on the Microscopic Doublet, published in the *Phil. Trans.* for 1829. This eminent philosopher, whose ingenuity never failed in executing in the best manner whatever he attempted, was then on his deathbed; and this, among other papers, was published without that complete revision which its author would otherwise have given it.

"The state of my health," says Dr Wollaston, "induces me to commit to writing rather more hastily than I have been accustomed to do, some observations on microscopes; and I trust that, in laying them before the Royal Society, they will meet with that indulgence which has been extended to all my former communications.

"In the illumination of microscopic objects, whatever light is collected and brought to the eye beyond that which is fully commanded by the object-glasses, tends rather to impede than to assist distinct vision.

"My endeavour has been, to collect as much of the admitted light as can be done by simple means to a focus in the same plane as the object to be examined. For this purpose I have used with success a plane mirror to direct the light, and a plano-convex lens to collect it; the plane side of the lens being towards the object to be illuminated."

These two principles of illumination, the first of which is the same as the first and fifth of the rules already given, though not so fully developed, and the second of which is founded upon a mistaken principle, have been carried into effect by Dr Wollaston in the following manner:—

"T, U, B, E represents a tube about 6 inches long, and of such a diameter as to preclude any reflection of false light from its sides; and the better to insure this, the inside of the tube should be blackened. At the top of the tube, or within it at a small distance from the top, is placed either a plano-convex lens UT, or one properly curved, so as to have the least aberration, about $\frac{3}{4}$ths of an inch focus, having its plane side next the object to be viewed; and at the bottom is a circular perforation A, of about $\frac{3}{10}$ths of an inch diameter, for limiting the light reflected from the plane mirror R, and which is to be brought to a focus at *a*, giving a neat image of the perforation A, at the distance of about $\frac{8}{10}$ths of an inch from the lens UT, and in the same plane as the object which is to be examined. The length of the tube, and the distance of the convex lens from the perforation, may be somewhat varied. The length here given, 6 inches, being that which it was thought would be most convenient for the height of the eye above the table, the diameter of the image of the perforation A must not, excepting with lower powers than are here meant to be considered, exceed $\frac{1}{20}$th of an inch.

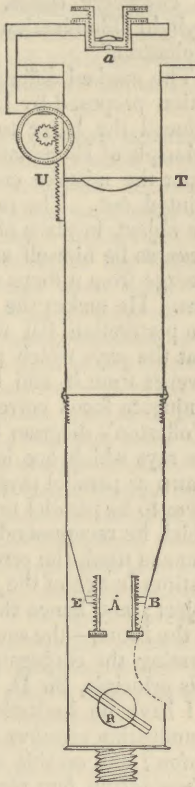

Fig. 95.

"The intensity of illumination will depend upon the diameter of the illuminating lens and the proportion of the image to the perforation, and may be regulated according to the wish of the observer. * * *

"The lens UT, or the perforation A, should have an adjustment by which the distance between them may be varied, and the image of the perforation be thus brought up to the same plane as the object to be examined. * *

"For the perfect performance of this microscope, it is necessary that the axis of the lenses, and the centre of the perforation A, should be in the same right line. This may be known by the image of the perforation being illuminated throughout its whole extent, and having *its whole circumference equally well defined.* For illumination at night, *a common bull's-eye lanthorn may be used with great advantage.* * * *

"Supposing the plano-convex lens to be placed at its proper distance from the stage, the image of the perforation may be readily brought into the same plane with the object, by fixing temporarily a small wire across the perforation with a bit of wax, viewing any object placed upon a piece of glass upon the stage of the microscope, and varying the distance of the perforation from the lens by screwing its tube *until the image of the wire is seen distinctly at the same time with the object upon the piece of glass.*"

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[1] This is the earliest suggestion of oblique illumination for developing structures.

In the preceding passages we have extracted every one of Dr Wollaston's observations in reference to his method of illuminating microscopic objects, so that the reader will be enabled thoroughly to understand it.

This method of illumination was highly commended by optical writers. Dr Goring[1] considered it as most effective, and enumerates it among the inventions which founded a new era in the history of the microscope; and he elsewhere states, that "there is no modification of daylight illumination superior to that invented by Dr Wollaston."[2]

The marked difference between the methods of illumination proposed by Dr Wollaston and Sir David Brewster induced the latter to publish, in 1831, a paper "On the Principle of Illumination of Microscopic Objects."[3] In this paper the mistake committed by Dr Wollaston is clearly pointed out. The rays which Dr Wollaston throws upon the object, in place of being *rays actually converged to a focus*, as he himself says they ought to be, are rays which diverge from a focus situated between the object and the lens. He makes the focal point of the circular margin of the perforation fall upon the object, without considering that the rays which pass through that perforation do not diverge from it, and therefore cannot be collected in the conjugate focus corresponding to the perforation. In Dr Wollaston's diagram (*Phil. Trans.* 1829, plate ii., fig. 1), the rays which are incident on the mirror R are actually drawn as parallel rays; and it is quite clear that he meant them to be parallel rays issuing from the bull's-eye lanthorn which he recommends. But if we suppose that a common flame is used, the error is just of the same nature. It is a distinct image of the *flame* that should be thrown upon the object; and hence the perforation A should be placed close to the flame,—the source of light and the illuminated object forming the conjugate foci of the lens. After explaining this principle, Sir D. Brewster adds in the same paper:—"I have no hesitation in saying, that the apparatus for illumination *requires to be as perfect as the apparatus for vision*; and on this account I would recommend *that the illuminating lens should be perfectly free of chromatic and spherical aberration, and that the greatest care be taken to exclude all extraneous light, both from the object and from the eye of the observer.*"

At the meeting of the British Association at York in 1831 the preceding methods were communicated to Mr Potter, who was then engaged in inquiries with the reflecting microscope, and who had used only the common method of illuminating his objects. The effect which he obtained by it, is thus described:[4]—"I am indebted to Dr Brewster for information on the necessity of having the focus of the illuminating lens for transparent objects to fall exactly upon the object, when great nicety of vision is required. Having adjusted my microscope carefully on this point (see our figure 71, where the object is seen in the focus of the illuminating rays), I saw quite easily what are called the diagonal lines on the scale from the white-cabbage butterfly, which has been proposed as a difficult test-object by Dr Goring; and it is such a one as those who have only seen the stronger longitudinal striæ on scales from the wings of moths and butterflies have little idea of." By the same means Mr Potter's instrument "showed him easily, not only the striæ on the scales of the wing of the small house-moth, but also the diagonal lines." Mr Potter afterwards applied his microscope, and the new method of illumination, to "a much more difficult object than those just referred to." This object is the broad bluish band first noticed in the web of the spider, the *Clubiona atrox*.[1] "There can be no doubt," says Mr Potter, "that this blue band consists of lines produced by the spider, and woven into the delicate tissue. To demonstrate these fibres, however, is a work for an expert microscopist provided with a first-rate instrument. So critical a defining power is required, at the same time with a large quantity of light, that I doubt much whether any compound refracting microscope, even the best achromatic, will ever show the construction of this web on a transparent object. When viewed in this manner through good common compound microscopes, the blue band can scarcely be perceived at all with a moderately high power. It is better seen as an opaque object by the light of the sun, and it was on this method that I discovered it, when highly illuminated and highly magnified, to be covered very regularly and closely with white spots. This was sufficient information that it was of a uniform texture; but as there is always in such a light a strong display of irradiations and prismatic colours, it was impossible to trace the fibres. I had discovered something of the texture with small globules of glass, used after the manner prescribed by Leuwenhoeck; but with very high powers the distinct field of view is so small that I dared hardly to pronounce decidedly upon the general structure; *and it was only after adjusting the illuminating lens of my microscope very carefully that I saw with it the complete structure of a regularly woven net.*"[2]

After this strong testimony to the practical utility of Sir David Brewster's method of illumination, and the unquestionable optical principles on which it is founded, we were surprised to observe that Dr Goring and Mr Pritchard should, in the *Microscopic Cabinet*, published in 1832, still recommend and use a method so decidedly erroneous in theory, and founded on no optical principles whatever. Dr Goring has described what he calls an improved illuminator, which is just Dr Wollaston's with a stop in the focus of the lens.

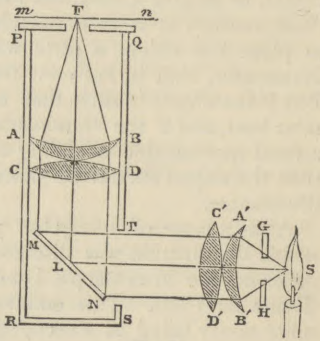

Fig. 96.

As the progress of discovery with the microscope must depend upon the scientific illumination of the objects under examination, we shall proceed to describe in detail the method of illumination used by Sir David Brewster. Let *mn* be the plane surface on which the object rests accurately perpendicular to the axis of the lens, lenses, or mirrors, which constitute the microscope. Let PQRST be a tube from 1½ to 2 inches long, and wholly lined with black velvet. This tube has an opening at ST, and must be so attached by an universal joint, or any analogous contrivance, to the slider-holder or stage, that the axis FL of the tube can be inclined at any angle to the surface *mn* from 90°, its general position, to 60° or less, for the purpose of oblique illumination. It should also have a circular motion about its axis, in order that the inclination may be made in any azimuth.[1] A doublet AB, CD, of no aberration, and having a focal length of from half an inch to an inch, is then placed in the tube, with a rack and pinion, or any other adjustment, to bring its focus for parallel rays F, or its conjugate focus for diverging rays, accurately to a point in the plane *mn*, and upon the object lying in that plane, for examination. A short way below it is placed a metallic speculum (not a silvered glass one), which receives parallel or diverging rays, entering the tube at ST, and reflects them upon the doublet ABCD. This speculum should be of pure virgin silver, notwithstanding its liability to tarnish, and should be wrought with the same care as the plane speculum of a Newtonian telescope;[2] or it might be a rectangular prism of good homogeneous glass, acting by total reflection. This part of the illuminator forms part of the microscope.[3] The other part of the illuminator, which is detached, is no less essential. It consists of the flame S, which should be as bright and small as will give the necessary quantity of light after condensation. As close to it as possible is placed a stand for holding a screen, with different circular apertures, and a variable rectilineal aperture. If a stronger light is required than can be obtained from the plane S, its light must be condensed into a parallel beam SL by another doublet of no aberration, A′B′C′D′ the flame S being in its anterior focus.

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[1] *Microscopic Illustrations*, Exord., p. 1, Lond. 1830.

[2] *Microscopic Cabinet*, p. 181, Lond. 1832.

[3] *Edinburgh Journal of Science*, New Series, No. xi., p. 83.

[4] *Ibid.*, p. 64.

[1] It is found in the crevices of old walls, and may be recognised by its irregular fleecy-looking web.

[2] Mr Pritchard received from Mr Potter a specimen of this web; but though he detected the *blue* bands, yet, as the specimen was not a recent one, he was unable to perceive "the complete structure of a regularly woven net." (*List of* 2000 *Microscopic Objects*, pp. 6, 7.)

The illuminator, as now described, is adapted to homogeneous light, either as obtained from a monochromatic lamp, or by means of coloured glasses, or from the prismatic spectrum; but if we employ common light, the doublets ABCD, A′B′C′D′ must be achromatic. We have mentioned above a variable rectilineal aperture. This is a most essential accompaniment for giving perfection to the vision of lined objects. The aperture should be made to form every possible angle with a vertical line, and should be opened and shut by means of a screw till as much light is introduced as is necessary to obtain a perfect view of the object. The image of the slit, which is close to the flame, must be thrown upon *mn*, so as to be parallel with the lines of the object, or to form any angle with them. When the objects are circular, circular apertures are preferable to any other.

We have already stated that no light should reach the eye, either from the field of the microscope or any other source. For this reason it would be desirable to have circular and rectilineal apertures of different sizes, to be placed immediately beneath *mn*, so as to allow no part of the field to be seen, excepting that which is occupied by the object, or part of it, under examination.

The above apparatus being provided, let us suppose that the observer is called to examine some structure very difficult to be resolved, such as the blue band of the *Clubiona atrox*, or the structure and nature of the lines and test-objects. We omit at present the consideration of the preparation of the object and the eye of the observer, and also the nature of the light which he is to use, as these will be separately considered; and confine ourselves to the use of the illuminator. The object is first placed on a piece of thin colourless parallel glass, or film of topaz or sulphate of lime, near its middle, and the microscope is directed to it, so that it can be seen distinctly in the ordinary way. Put the illuminator in its place, and set the proper aperture close to the small plane. Adjust the doublet ABCD by its screw or pinion till a distinct image of the aperture GH is seen in the field; and, by means of the apertures below *mn*, any stronger or unnecessary light may be still more completely excluded. If the structure is not rendered sufficiently distinct by this process, it will be proper to try the effects of *oblique illumination* by inclining the axis FL of the illuminator to the plate *mn*, and observing carefully the effects which it produces in different azimuths. If all these means are insufficient, we must have recourse to new auxiliaries,—to monochromatic light, if the microscope is not achromatic, or to monochromatic illumination, if it is achromatic; and we must prepare both the eye and the object, the one for exhibiting and the other for viewing to the best advantage the structures which we are anxious to develop.

As the method of illumination which we have described has been neither understood nor appreciated by some writers on the microscope, the following observations may be useful:—If we examine with a polarizing microscope certain minute fibres which depolarize light, we shall, with high powers, see them very indistinctly, owing chiefly to the fringes formed by diffraction; but if we examine them when the field is dark and the fibres alone luminous, they will be seen with great distinctness, and unaccompanied with fringes. The reason of this is, that no light passes by their edges, so that no diffraction fringes can be formed either within or without their image.[1] They are seen as if they were self-luminous. In like manner, a fine wire made red hot, if examined in a dark field, will be unaccompanied with fringes. Hence it appears that if we can converge light upon a transparent object so that the points of convergence or the foci of the rays fall upon the object, the light will, as it were, radiate from the parts of the object which they illuminate as if they were self-luminous; and consequently there will be no diffraction fringes. The light, therefore, must be either achromatic or monochromatic. Hence it follows that a common lens which has different foci for the different colours of the spectrum, and also for different parts of its surface, is unfit for microscopic illumination.

These views have been adopted by the most distinguished opticians, as well as by the most eminent observers, and all the finest instruments are accompanied with an achromatic condenser or illuminator.

This method of illumination was, as we have already stated, proposed by Sir David Brewster in 1831, and used by Mr Potter in the same year. It was more fully described by the inventor in this work in 1837, and in his separate Treatise on the Microscope published in the same year;[2] and yet the very same apparatus was communicated to the Academy of Sciences in Paris as a new invention, by M. Dujardin, and published in September 1838.[3] It can hardly be expected that foreigners should be acquainted with every English invention, and we have no doubt that M. Dujardin had not seen the books to which we have referred; but it is discreditable to the science of England that the authors and compilers of English treatises on the microscope should continue to ascribe to M. Dujardin an invention which has not only been used in their own country for 25 years, but distinctly described in English works, easily accessible, and well known in the scientific world.

Before we conclude this chapter we must gratify the reader with an account of Mr Wenham's very ingenious

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[1] This contrivance, though published twenty years ago, has been recently brought forward as a new invention by Mr Sollit in the *Quarterly Microscopical Journal*, 1855, vol. iii., p. 88.

[2] Such specula may now be made by the observer himself by the beautiful method of depositing a layer of silver upon glass, invented by Mr Power—a method which M. Foucault has applied with great success to the construction of specula for reflecting telescopes. We have had occasion to see at the Imperial Observatory in Paris two excellent telescopes thus made by M. Foucault, one 18 inches, and another about five feet in focal length.

[3] If the axis of the microscope is placed horizontally, or even with some obliquity, we may dispense with this speculum altogether, and direct the tube at once to the illuminating flame.

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[1] These views are successfully explained in the *Phil. Mag.*, 1848, vol. xxxii., p. 161.

[2] See also the *Phil. Mag.*, 1848, vol. xxxii., p. 163.

[3] *Comptes Rendus*, &c., Sept. 10, 1838, tom. vii., p. 620.

method of illuminating opaque microscopic objects when object-glasses of very high power are employed. It is impossible to apply a Lieberkhun to objects covered with a plate of glass,[1] and equally so to throw in upon the object reflected light sufficient to illuminate it. Mr Wenham has therefore conceived the ingenious idea of illuminating the object by light that has suffered total reflection from the interior of the upper surface of the thin glass which covers the object. The method of doing this is shown in the annexed figure, where *aa* is the surface of the plate of glass upon which the object is laid, and *mn* the thin glass which covers the object, with Canada balsam or some other fluid interposed. The frustum *b* of a hemispherical lens is placed beneath the slide *aa*, with water or any other fluid interposed. When rays *c, c, c, c* fall perpendicularly through the sides of the lens *b*, they will pass on to the upper surface *mn* of the thin glass cover, and if they fall at the proper angle upon that surface, they will be wholly reflected upon the object between the two glasses.[2] By placing a small highly dispersing prism beneath *aa*, so as to form a fine spectrum from a narrow slit, the most perfect monochromatic illumination may be obtained. The prism may be very near the hole, as a spectrum of very little length is required.

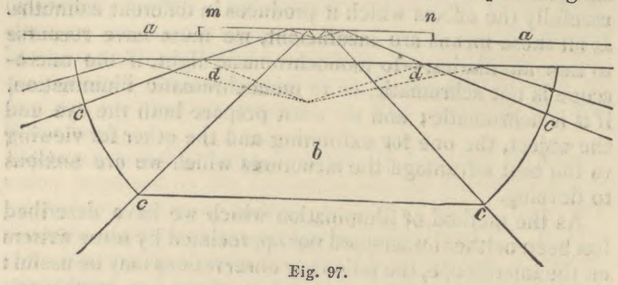

Fig. 97.

In order to illuminate objects obliquely by condensed light, a prism, called Amici's prism, which is the same as Newton's curvilineal prism, has been used; but it is obvious that the lenticular reflecting prism, or the plano-convex lens used as a reflector, as shown in fig. 21, is much superior in accuracy, and much more easily made. To place two spherical faces upon a prism, so as to have the same centre and the same inclination to the base, is a very difficult operation; whereas, in the lenticular reflector the centres are necessarily coincident and equally inclined to the base.

CHAPTER VII.

ON THE MONOCHROMATIC ILLUMINATION OF MICROSCOPIC OBJECTS.

Monochromatic illumination of microscopic objects.

If a simple and easily applied system of monochromatic illumination, that is, of illuminating objects with homogeneous light—which a prism, and consequently a lens, is not capable of dispersing or refracting in different directions—could be contrived, we should never again hear of compound achromatic microscopes. We believe it will be admitted that in Sir John Herschel's doublet of no aberration the spherical aberration is more completely corrected than in any double, or even triple, achromatic object-glass. Hence it follows, that in homogeneous light such a doublet would be a better microscope than the compound lens. But in the best system of achromatic compensation that can be executed the secondary spectrum still remains without a remedy; and hence the doublet of no aberration, in which there can be no secondary colour in homogeneous light, must be a superior instrument to the compound achromatic lens. Now, in telescopes it is impossible, except in viewing the sun's disc,[1] to work with homogeneous light; but in microscopes, where the quantity of light is in our power, it is perfectly practicable to make that quantity so great that all the yellow or red rays which it contains may give sufficient light for microscopical observations. This insulation of homogeneous light may be effected in three ways; first, by a monochromatic lamp, as proposed and constructed by Sir David Brewster; secondly, by the absorption of coloured media; and thirdly, by the prism.

1. The monochromatic lamp is shown in the following figure, where AB is a lamp having its globe A filled with diluted alcohol, which descends gradually through the tube C into a thin platina or metallic cup, in which it burns. A strong heat is kept up by a spirit-lamp inclosed in a dark lanthorn, and when the diluted alcohol is inflamed, it will burn with a fierce and powerful yellow flame. If the flame should not be perfectly yellow, or rather of a *nankeen* colour, owing to an excess of alcohol, a small proportion of salt thrown into the cup D will have the same effect as a farther dilution of the alcohol. Sometimes a little blue light will be found mixed with the yellow, but this may be easily absorbed by a piece of yellow glass placed on any part of the microscope through which the rays pass. Although this light is feeble compared with that of white flames, yet, by using larger lenses for condensing it, it is quite easy to obtain a pencil sufficiently powerful for all microscopic observations.[2]

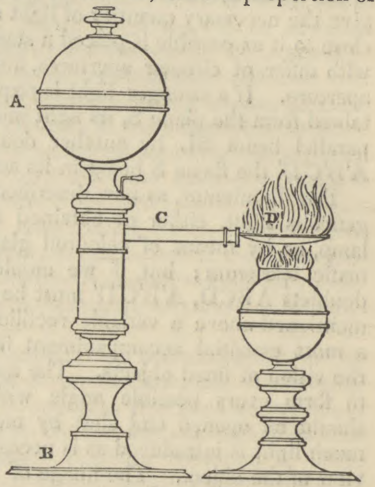

Fig. 98.

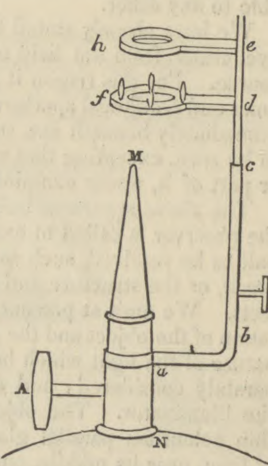

Fig. 99.

A stronger flame may be produced by using a gas lamp, or, what is still better, a portable gas one containing compressed gas.[3] This gas, when rushing out in a full stream, explodes when burned with atmospheric air, emitting much heat and a faint bluish and reddish light. As the force of the issuing gas is sufficient to blow out the flame, a contrivance for sustaining it becomes necessary. The method which we contrived for this purpose is shown in the annexed figure, where N is the main body of the lamp, MN the principal burner, and A the screw which opens the main cock. A small gas tube *abc*, communicating with the main burner, terminates above the burner, and has a short tube *de* movable up and down within it, but so as to be gas light. This tube *de*, closed at *d*, communicates with the hollow ring *fg*, in which four apertures are perforated so as to throw their jets of gas to the apex of a cone whose base is *fg*. When the gas is made to issue from the burner M, it rushes also into the tube *abcdf*, and issues in four small flames at the apertures in the ring *f;* and the height of these flames is regulated by the stop-cock at *b*. The explosive mixture of air and gas which rushes up through the ring is sustained in combustion by these small flames, through which it passes. A broad collar, made of coarse cotton-wick, and thoroughly soaked in a saturated solution of common salt, is fixed on a ring *h*; and when the bluish flame of the explosive mixture rises above *h*, it will be converted by the salted collar into a strong mass of homogeneous yellow light. A hollow cylinder of sponge, with numerous projecting tufts, may be substituted for the cotton collar, or a collar of abestos cloth might be used, and supplied from a capillary fountain containing a saturated solution of salt.[1]

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[1] Mr Ross, we understand, has contrived a Lieberkhun for his highest powers to illuminate uncovered opaque objects.

[2] *Microscopical Journal*, vol. iv., p. 58.

[1] A *solar telescope* should never be an achromatic one, but should consist of a compound lens of no aberration, all the colours of the spectrum but one being absorbed by the darkening glass. One of these telescopes, in which the object-glass is corrected for spherical aberration upon Sir John Herschel's principle, was constructed for Sir David Brewster by Dollond, at the expense of the Royal Society of London, and has been used in his observations on the lines of the spectrum.

[2] *Edinburgh Transactions*, vol. ix., p. 435.

[3] When this was written, such lamps were used in Edinburgh, and supplied by a company which did not succeed.

When the few blue rays which sometimes mingle themselves with this yellow light are absorbed, every part of the light will be found to have a definite refrangibility, greater than any other artificial light that can be produced. The minutest objects and the smallest type will appear perfectly distinct in this light when seen or read through the largest possible angle of the greatest dispersive prism,—an irrefragable proof of the perfect homogeneity of the light.

2. The second method of producing homogeneous light, and by far the simplest and most easily applicable to microscopes, is that of absorption ; and the best rays to leave unabsorbed or insulated are the red. It requires some experience and scientific knowledge of the action of different absorbing media to select those which will leave the *narrowest and brightest band* of the *red* space in the spectrum. We have now under our microscope (a grooved sphere of garnet executed by Mr Blackie[2]) two scales of a moth lying in sulphuric acid and covering each other. With solar light the spaces between the lines glitter with all the hues of the rainbow ; but when a thickish plate of red mica is combined with another plate of red glass, and placed beneath the object, all these colours instantly disappear, and a perfection of vision is obtained, which can be disturbed only by the very small portion of spherical aberration which must exist in the sphere, and which an increased depth of the groove would render almost insensible. Blue glasses, and green and yellow as well as coloured fluids, may be successfully used in narrowing the range of refrangibility of the red space.

3. The third method, or that of prismatic refraction, is perhaps the surest and the best method of obtaining homogeneous light with the smallest extent of refrangibility. A certain effect may be produced by small prisms ; but in order to have a perfect apparatus, the *microscope should form part of the apparatus for examining the lines of the solar spectrum ;* that is, it should screw into the eye-piece of the telescope, in front of the object-glass of which is placed a fine large prism, for forming the spectrum within the telescope. By this method, which we have put to the test of experiment, microscopical observations can be carried on with an accuracy and satisfaction which nothing can exceed. We enjoy the luxury of perfectly monochromatic vision greater than which the most perfect achromatic compensation cannot give ; and while we have the spherical aberration corrected, we have *no secondary colours*, and none of the imperfections of vision which must arise in transmitting light through six or eight lenses of plate and flint glass.

Although we hope the scientific reader will admit that the preceding views are demonstrably correct, yet Dr Goring has pronounced a most unfavourable opinion of the system of monochromatic illumination.[1] We endeavoured to convert him from this heresy, and hoped that we had succeeded ;[2] but in the *Micrographia*, since published, he devoted a whole chapter to the reproduction and support of his former views.[3] We shall therefore again examine his objections in their order, as they obstruct the progress of improvement among those who justly admire Dr Goring's ingenuity and knowledge in everything which relates to the microscope.

1. Dr Goring's first objection to monochromatic illumination is, that it is too weak, and must be about one-seventh of the whole beam of light. This we are not disposed to dispute ; but Dr Goring is too well acquainted with the resources of optical science, to forget that this monochromatic *seventh* of a beam of light may be made *seven* times more intense than the whole beam. The objection, however, does not apply to the solar spectrum, for one-seventh of the sun's light is too intense for any eye to bear.

2. The second objection of our author is, that the colours of the spectrum, when separated by the prism, are actually separated into different colours when they are refracted in oblique pencils by a microscope. If this observation is correct, then we must denounce the prism that produced such a spectrum as utterly useless. Dr Goring, however, conceives his observation and his prism to be good, and endeavours to explain the result by referring to Sir David Brewster's analysis of the spectrum, in which it is shown that white light exists at every point of it ; but this white light, which has been rendered visible by absorption, cannot be decomposed by refraction of any kind, as it consists of *red*, *yellow*, and *blue* rays, of the same refrangibility. Such white light is the light that is wanted for the microscope ; and there can be little doubt that absorptive media will yet be discovered to effect its insulation in sufficient quantity for practical purposes.

3. Another objection to monochromatic light is, that it will not show the real colours of microscopic bodies. This is true ; but the *object of the microscope is not to find out colours but structures.* A common glass lens, with common light, will let the observer know all that he wants of the colours of objects ; and when he has learned this, he will then gladly avail himself of coloured light for more important purposes. We can truly say, that though we have wrought with the microscope for fifty years, we do not at present recollect a single case where we required to know anything of the precise colours of minute bodies. Notwithstanding this discussion, Dr Goring concludes his chapter with the following observation, in which we entirely concur :—" A monochromatic light, therefore, being once obtained *in a sufficient state of intensity for practical purposes*, bids fair to conduct us to the highest perfection of which aplanatic object-glasses and magnifiers are susceptible." It may be proper to add, that the best system of compound achromatic object-glasses now in use would be freed of all their secondary colours by using monochromatic light ; and they may be also greatly improved by employing suitable coloured media to absorb what are called the outstanding rays in an achromatic combination. Although Dr Goring has objected to the use of monochro-

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[1] *Edinburgh Journal of Science*, New Series, No. 1, p. 108.

[2] This sphere, which we have already mentioned, is made of the purest garnet, and is executed in the most admirable manner ; and though we cannot say that we see any defect in it, yet if the groove were still deeper, both its spherical and achromatic aberration would be diminished.

[1] *Edinburgh Journal of Science*, New Series, No. 9, p. 52.

[2] *Ibid.*, p. 143.

[3] *Ibid.*, 73.

matic light, he has himself given some remarkable illustrations of its value, as removing entirely the effects of chromatic aberration.[1]

CHAPTER VIII.

ON THE PREPARATION OF THE OBJECT AND THE EYE FOR MICROSCOPICAL OBSERVATIONS.

In using lenses of short focus, either singly or in doublets and triplets, the object is so near the lens, and its thickness, even when very small, forms such a considerable part of its distance from the nearest refracting surface, that any bend or want of flatness in the object completely interferes with the distinct vision of its parts. When the object will bear pressure, the best way is to lay above it a thin transparent film, with perfectly parallel and polished surfaces, such as a splinter of New Holland topaz, a thin plate of sulphate of lime, or a film of mica.[2] If these plates are a little less thick than the distance between the lens and the object, a little bees' wax should be interposed between the brass setting of the lens and the plate, so that the lens in the act of adjustment would press the wax against the plate, and the plate against the object, till distinct vision is obtained. The object should be placed upon a deeply-curved concave surface.

The proper flattening of the object, when it is tender, may be effected by pressing a thick balsam above it, and allowing the lens to dip into the balsam. If the surface of the lens is flat, its magnifying power will suffer no diminution.

When grooved spheres are used, such as the garnet one above mentioned, the object requires to be very near its surface. It should therefore be placed in a concave lens of glass, of a little greater radius than the sphere, and pressed into the concave form by interposing a narrow strip of a thin film of mica, and, if necessary, pieces of wax or India-rubber, as before; the pieces filling up the space between the lens and the mica, so as not to interfere with the part of the object under examination.

If a diminution of the magnifying power can be permitted, a fluid may be placed between the concave object-plates and the grooved sphere, and the chromatic aberration greatly reduced. By the interposition of a fluid, a grooved diamond sphere may be used; for though its focus for parallel rays falls within the sphere when the refractions are made from air and into air, yet, when the first refraction is made from a suitable fluid, the focus will fall without the sphere.

When the object is put into the best possible condition for observation, and the illuminator applied in the best possible manner, the observer will have every advantage in his researches; but still the structure which he seeks to develop may escape his eager research. Under these circumstances, he must perform his part of the observation in the best possible manner.

Unless particular arrangements are made by the observer for his own comfort, there is no bodily fatigue to be compared with that of the use of the microscope. The eye, the mind, and the whole frame, are on the stretch. The observer must therefore first try if his own eye is in a right state for observation. The fluid which lubricates the cornea, which must be considered as a lens and as part of the microscope, is sometimes in such a viscid state, that when the eyelids roll over the cornea by that beautiful provision of nature by which it is kept smooth and clean, the lubricating fluid, which is pushed into a ridge between the eyelids, does not quickly recover a convex surface. This state of the cornea is incompatible with delicate microscopic observations, and its existence may be ascertained by viewing the expanded image of a luminous point held close to the eye, and, after shutting the eyelids and again opening them slowly, observing if the luminous disc recovers its uniform luminosity quickly or slowly. If the luminous line produced by the fluid accumulated between the eyelids continues to be visible, and the general surface mottled and spotted, the lubricating secretion should be excited by exposing the eye to the vapour of hartshorn, raised by pouring a few drops on the surface of boiling water. The secretion will now flow copiously, the cornea will be swept clean by the purer and less viscid fluid, and the vision of the observer greatly improved. But this movable fluid surface of the cornea generates another imperfection of vision, which has already been referred to. This fluid, when undisturbed by the eyelids, descends by the influence of gravity in vertical lines, and the minute ridges thus formed obliterate and render indistinct all horizontal lines seen by the eye, but have a tendency rather to improve the vision of vertical lines. In proof of this, we may state the unquestionable fact, that if we take a striped pattern of any fabric, and bend part of it into a horizontal direction, while the rest remains vertical, or *vice versa*, the vertical part will always appear the most distinct. Hence, in viewing lined objects, when the position of the observer's head is either vertical or oblique, the lines of the lined object should be always placed parallel to the direction of the descending fluid. If the axis of the lenses is vertical, and the eye looks downwards, the lubricating fluid will collect irregularly at the apex of the cornea, and injure vision. If the axis of the lenses is horizontal, and the observer's head in its natural position, the fluid will descend in vertical lines; but if the observer lies on his back and looks into the microscope upwards, a position, we admit, not favourable for research, the fluid will flow equally in all directions from the apex to the margin of the cornea, and leave a clear centre well fitted for distinct vision. We may here notice the beautiful contrivance, not mentioned by natural theologians, that the effect of the vertical descent of the lubricating fluid is counteracted by the eyelids opening horizontally, and consequently effacing the tendency of the fluid to form vertical currents. Had the eyelids opened vertically, the vertical ridges would have been increased, and vision greatly impaired.

When everything has been done to fit the *cornea* (the only part of the eye over which we have any direct command) for accurate vision, the general state of the health, or any casual irregularity of diet, or the accumulation of those minute transparent vessels which produce *muscæ volitantes*,[1] will be sometimes found to affect the state of the organ, and unfit it for nice observation. To remedy this defect of vision, we must refer the patient to the prescriptions of his physician.

When these precautions have been taken, the observer must protect his eye from all extraneous light; and the most effectual way of doing this is to use the snow spectacles of the Greenlanders, which are cut out of wood, so as to exclude all light whatever, except what enters through a circular aperture the size of the pupil, and directly in front of it.[2] A cast should be taken in plaster of Paris, from the part of the face to which they are to be applied, to enable the artist to cut them of a proper shape; and when finished they should be lined with black velvet.

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[1] See Pritchard's *Microscopic Illustrations*, pp. 271, 272, 3d edit., 1845.

[2] Plates of very thin glass are now made for the express purpose of inclosing objects for the microscope.

[1] See *Edinburgh Transactions*, 1843, vol. xv., p. 377.

[2] In the snow spectacles a long narrow slit is used, to enable the wearer to look on each side of him. An interesting account of the great value of these spectacles, by the celebrated Professor Blumenbach, will be found in the *Edinburgh Phil. Journal*, vol. viii., p. 261.

The last requisite for accurate microscopical observation is *steadiness in the microscope*,[1] and a steady and comfortable position for the observer. The first is easily attained; the second may be accomplished by the observer resting his doubled arms upon a stool or frame nearly the height of the eye-glass of the microscope, but unconnected with it, while his chin rests either upon his arms or upon his breast.

When all these means and precautions fail in unravelling a mysterious structure, we have often derived advantage, in the case of lined objects, by looking through cylindrical lenses or good prisms; the length of the cylinder, or the refracting edges of the prism, being at right angles to the lines. Narrow slits may also be used with advantage next the eye; but in all these cases, while we improve and give a finer definition to the lines and the spaces between them, we deteriorate vision for other parts of the structure.

CHAPTER IX.

APPLICATION OF PHOTOGRAPHY TO THE MICROSCOPE.

Photography may be applied to the microscope in two ways,—1*st*. In furnishing us with magnificent photographs of microscopic objects; and, 2*d*. In converting, for special purposes, large objects into small ones which are visible only in the microscope.

1. Mr Richard Hodgson seems to have been the first person who obtained microscopic photographs upon daguerreotype plates by the sun's direct rays. In Oct. 1852 Mr Joseph Delves, of Tunbridge Wells, exhibited to the Microscopical Society beautiful magnified photographs both on paper and glass,[2] namely, the spiracle and trachea of the silk-worm, magnified 60 diameters, and the proboscis of the fly magnified 180 diameters. In November Mr George Shadbolt exhibited a photograph of a fly's proboscis, taken by a very small camphine lamp.

The method of taking these pictures is very simple. The eye-piece of the microscope being removed, the end of the tube from which it was taken is fixed into a dark box (or a photographic camera), at the opposite end of which is a groove for carrying the ground-glass plate. When the object is well illuminated either by solar or artificial light, a distinct picture of the object is thrown upon the ground-glass plate, and the sensitive plate is placed so as to be in the chemical focus of the object-glass, which, in low powers, is at some distance beyond the luminous focus.

Mr Shadbolt obtains the chemical focus by altering the luminous focus by the fine adjustment; an alteration of two turns of the milled head, or $\frac{1}{50}$th of an inch, being sufficient for an inch-and-half object-glass; an alteration of half a turn for a $\frac{2}{3}$d inch object-glass, or $\frac{1}{200}$th of an inch; and an alteration of about 2 divisions, or the $\frac{1}{1000}$th part of an inch, for a $\frac{4}{10}$th of an inch object-glass. The time of exposure varies from 1 to 10 minutes.[3]

Mr F. H. Wenham has greatly improved the process of microscopic photography by using the ordinary microscope as a solar one, and using a dark room in place of a camera, by a new mode of combining the chemical and visual foci, and by obscuring for a time the parts of the object which are either easily solarized and lost, or out of focus. He prefers sunlight to artificial light, though he justly considers it of great importance to have what he calls a *photographic fusée* that will burn with the necessary actinic power for sufficient time to take nocturnal or underground photographs. He has produced photographic pictures by burning phosphorus, by balls of fine zinc turnings, by a succession of electric sparks, and by the oxyhydrogen or lime light.

Mr Wenham has succeeded in obtaining by the photographic microscope the markings on the most difficult tests. One of these, of the *P. angulatum*, magnified about 15,000 diameters, shows the configuration of the markings, perfectly black and distinct, in a far greater degree than we can ever hope to see them through the compound microscope; and Mr Wenham is of opinion "that if ever the structure of those difficult tests is to be proved, it will be by the aid of photography."[1]

Microscopic photographs by M. Bertsch.

Photographs of a still more minute character were presented to the Academy of Sciences on the 10th August last by M. Bertsch.[2] They were five in number.

The *first* was one of the Diatomaceæ, from guano, obtained by a magnifying power of 500 diameters. The focal length of the object-glass was the 50th of an inch (a demi-millimetre). It was achromatized for the superior rays of the spectrum, and its chemical focal length was 24 centimetres. The focus for the inferior rays was the $\frac{1}{180}$th of a millimetre from the luminous focus.

The *second* specimen was two Naviculæ, of that species of which it is difficult to see the structure and the striæ with the best microscopes. One is magnified 800 and the other 500 diameters. They were illuminated with light so oblique that the field of view was almost dark.

The *third* represented, with a power of 500, the globules of the human blood. The annular space and the depression were distinctly shown on a larger field than is given by the best microscope, and the light traversed them without changing its direction.

The *fourth* specimen consisted of two pictures of the crystals of salicine, seen in polarized light; the one illuminated by the ordinary, and the other by the extraordinary ray.

M. Hartnach constructed for M. Bertsch a complete instrument for taking this class of photographs, with a magnifying power of from 50 to 1000 diameters for transparent objects, and from 50 to 150 for opaque objects.[3]

2. Photography has been successfully applied in reducing, for special purposes, large objects into such small dimensions that they are invisible to the naked eye, and can be seen only with a good microscope.

Microscopic lines of writings by Sir John Barton;

By M. Nobert.

It has long been a trial of skill to include the Lord's Prayer in the smallest circle by the unaided hand of the writer. More recently results of the most remarkable kind have been obtained by machinery. Sir John Barton drew with a diamond point, upon steel, lines at the distance of the 10,000th of an inch. M. Nobert exhibited at the Crystal Palace in 1851 ten groups of lines upon glass in which the number of lines in an English inch varies from 11,265 to 49,910; and M. de la Rue examined another specimen of ten groups in which they varied from 11,261 to 56,306!

In order to see the lines in the widest of these groups, a power of 100 is sufficient, but one of 2000 is required to separate those in the closer groups. They thus become test-plates for determining the power and excellence of microscopes.

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[1] This suggestion has been specially attended to in the latest form of Mr Ross's microscope. He has obtained the most perfect steadiness by giving solidity to those parts which are most liable to tremor; and he attaches so much importance to this property of the instrument, that he tests it by the "inverted pendulum." The object of this apparatus is to exhibit vibrations which could not otherwise be perceived. He varies the size of the parts of the stand till he obtains such an equality of vibration between the stage and the body of the microscope as will prevent any visible tremor in the object under examination.

[2] They were produced in from 5 to 10 seconds in sun-light. With low powers "a moment's exposure" is sufficient.

[3] See *Transactions of the Microscopical Society*, vol. i., p. 57; and *Microscopic Journal*, vol. i., p. 165.

[1] *Transactions of the Microscopical Society*, vol. iii., p. 1.

[2] *Comptes Rendus*, &c., tom. xlv., p. 213.

[3] *Cosmos*, Aug. 14, 1857, vol. xi., p. 179.

By M. Froment.

Microscopic effects still more wonderful have been produced by M. Froment of Paris, one of the most distinguished artists of modern times. A piece of writing, for example, about $3\frac{2}{10}$ inches in diameter, was compressed into the space of $\frac{1}{30}$th of an inch. The mode of doing this has not yet been published; but Dr Lardner[1] informs us "that it consists of a mechanism by which the point of the graver or style (a diamond point generally) is guided by a system of levers, which are capable of imparting to it three motions in right lines, which are reciprocally perpendicular; two of them being parallel, and the third at right angles to the surface on which the characters or design are written or engraved. The combination of the motions in the direction of the axes, parallel to the surface on which the characters are engraved or written, determines the form of the characters; and the motion in the direction of the axes, at right angles to that surface, determines the depths of the incision, if it be engraving, or the thickness of the stroke, if it be writing."

By Mr Peters.

Wonderful as are the specimens published by M. Froment, they have been greatly surpassed by those produced by our countryman Mr Peters, who has invented and described the machine by which they are produced. Mr Peters has inscribed the Lord's Prayer in 6 lines in a rectangular space one of whose sides is the $\frac{1}{250}$th part of an inch, and the other the $\frac{1}{600}$th part of an inch; that is, the area of the rectangle is $\frac{1}{250} \times \frac{1}{600}$, or the $\frac{1}{150000}$th of a square inch. The height of each letter is the $\frac{1}{10000}$th part of a linear inch, and therefore the space occupied by any letter, such as *u* or *n*, which are as wide as they are high, is no more than the *hundred millionth of a square inch!*[2]

Microscopic photographs by Mr Dancer.

Among the wonders of microscopic photography not the least interesting and useful are the fine microscopic portraits taken by Mr Dancer of Manchester, and copies of monumental inscriptions so minute, that the figures in the one, and the letters in the other, are invisible to the eye. A family group of seven complete portraits occupies a space the size of the head of a pin; so that *ten thousand* single portraits could be included in a square inch. They are executed upon films of collodion as transparent as glass; so that a family group could be placed in the centre of a brooch, a locket, or a ring, and magnified by the central jewel cut into a lens sufficient to exhibit the group distinctly when looked into or held up to the light.

Microscopic copies of despatches and valuable papers and plans might be transmitted by post, and secrets might be placed in spaces not larger than a full stop or a small blot of ink.

We have already had occasion to mention in the article MICROMETER the application of photography in making micrometers and micrometrical scales of all kinds; and it is obvious that groups of test-lines like those of Nobert could be produced upon transparent collodion with an accuracy and distinctness greater than could be done upon glass. The original groups, drawn on a large scale either by the hand or a ruling-machine, could thus be copied and reduced *ad infinitum*.

CHAPTER X.

ON TEST OR PROOF OBJECTS FOR TRYING THE PERFORMANCE OF MICROSCOPES.

Test-objects.

This class of objects, and their application to the microscope, we owe to Dr Goring; and to their introduction we must ascribe much of the rapid improvement which this instrument has undergone. The finest test-objects are the scales of butterflies and moths, which were suggested to Dr Goring by the following passage in Leuwenhoeck:—

Test-objects. Leuwenhoeck.

"If we examine the wings of this creature (the silk-worm moth, *Phalæna mori*) by the microscope, we shall find them covered with an incredible number of feathers (scales), of such various forms, that if a hundred or more of them were to be seen lying together, each would appear of a different shape. To show more clearly this wonderful object, I caused eight feathers to be delineated, for I do not remember that I ever saw them of so curious a make in any flying insect.

"Although the microscope by which these feathers were drawn represented objects very distinctly, *the limner could not through it see the ribs or streaks in each feather until I pointed them out to him.* Therefore I put into his hands a microscope which magnified objects almost as much as that by which the silk-worm's thread was drawn, desiring him to give the figure of that feather which through it he could see the most distinct."[1]

Dr Goring.

From this passage Dr Goring naturally inferred, that there were some peculiar properties in the lines on the feathers and scales of insects, which rendered them more difficult to be discovered than other microscopic objects; and hence he discovered their properties as *test* or proof objects for trying the penetrating powers of microscopes. Dr Goring regards the *penetrating*[2] power of a microscope as dependent on its angle of aperture, and its *defining* power as in the inverse ratio of the quantity of chromatic and spherical aberration. When the angle of aperture was less than a certain quantity, he found that the lined structure of the scales could not be rendered visible, however perfect the instrument was.

Mr Pritchard.

These new and apparently important results were confirmed by Mr Pritchard; and since that time opticians, both in this and in foreign countries, have contended with each other in producing object-glasses with the largest angles of aperture. Mr Ross, as we have seen, has produced object-glasses $\frac{1}{12}$th of an inch focus, with an angle of aperture of 170°; and in a communication to Mr Quekett[3] from Mr Ross himself, he gives a history of the steps by which he advanced to this remarkable angle:—

Angles of aperture.

	Focal length.	Angle of aperture.
1832 Mr Ross	1 inch	14°
1833 Do.	„	18
1834 Do.	$\frac{1}{4}$ „	55
1836 Do.	„	15
—— Do.	$\frac{1}{8}$ „	60
—— Do.	$\frac{1}{10}$ „	72
—— Do.	1 „	22
—— Do.	$\frac{1}{8}$ „	63
1842 Do.	$\frac{1}{2}$ „	44
—— Do.	$\frac{1}{4}$ „	67
—— Do.	$\frac{1}{8}$ „	74
1844 Professor Amici	$\frac{1}{7}$ „	112
—— Mr Ross	$\frac{1}{8}$ „	85
—— Do.	$\frac{1}{12}$ „	135
—— Do.	$\frac{1}{12}$ „	170
—— Do.	$\frac{1}{16}$ „	—

In closing his communication to Mr Quekett, Mr Ross remarks *that* 135° *is the largest angular pencil that can be passed through a microscopic object-glass*, and yet he had increased it in 1855 to 170°. Some writers speak of angular apertures of 175°, and even 180°!

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[1] *Treatise on the Microscope*, 1856, chap. ii., p. 73.

[2] The ingenious machine invented by Mr Peters is described by Mr Farrants in the *Transactions of the Microscopical Society*, vol. iii., p. 55.

[1] *Select Works*, p. 63.

[2] Some writers have very unwisely substituted the term *resolving* in place of *penetrating*, and have applied the latter to a property of the microscope which all low powers possess; that is, seeing into an object, or seeing parts out of focus. The term *resolving*, applied to the telescope, is the power of separating minute luminous points.

[3] *Practical Treatise on the Microscope*, 1848, p. 430.

Angular aperture.

It is well known to every observer with the microscope that object-glasses of large angular aperture exhibit objects which are not seen with those of a smaller aperture and the same focal length; but it is equally well known that they often show objects *less distinctly than those of a smaller aperture.* This being the fact, we ask, What great advantage is derived from merely *seeing* that there are lines in an object, unless the object-glass shows us what is the nature and structure of these lines?

As instruments for studying structures and making useful discoveries with the microscope, let us compare the object-glass of large aperture with one of small aperture:—

1. It is obvious that, owing to the larger size of the lenses in the large-aperture lenses, the rays must pass through a much greater thickness of glass of *doubtful homogeneity.*

2. With large apertures, the spherical aberrations and the chromatic aberration, primary, and *secondary* especially, must be less perfectly corrected.

3. The surface of glass with the most perfect polish must have pores produced by the attrition of the polishing material, and light falling upon the sides of these pores with extreme obliquity must be refracted less perfectly than when incident at a greater angle.

Errors of large angular apertures.

4. The structures actually seen, however distinctly, and *even if the lenses are absolutely perfect*, are *false structures*, the falsehood of the picture being *proportional to the angle of aperture.*

This result, which the optician and the optical student will receive not only with scepticism, but we fear with disdain, as the photographers have done an analogous truth, may be illustrated in the following manner:—

It has been demonstrated[1] that all objects in relief are misrepresented by large lenses when their pictures are taken in the camera obscura. The human face divine is caricatured. Parts invisible are displayed, and parts visible are deformed. When Polyphemus admired Galatea she was not the beauty who fascinated Acis; and we think a national reward should be offered to the daring Ulysses who should extinguish the orb of every photographic Polyphemus in the land. But if the photographic lens thus deforms youth and beauty and age, and even trespasses upon inanimate nature, what may we not expect from the cyclopean eye of a twelfth-of-an-inch object-glass viewing microscopic objects in relief, several thousand times less in diameter, and so near it that it would see nearly the whole of its surface were it a sphere? For the purpose of illustration, we may suppose the microscopic object to be the head, in relief, of the Venus de Medicis, on a much smaller scale than the beautiful microscopic portraits of Mr Dancer of Manchester, and that the microscopical observer is requested to make a drawing of it. We cannot venture to say what would be its expression, but we are sure that it could have no resemblance to the original, both ears being fully brought out, and almost the whole round of the head. In like manner, every ridge in a microscopic object will show to the observer both its perpendicular sides as well as the side opposite the eye, and the resulting picture will be an incoincident combination of a thousand different pictures, as seen from every point of the object-glass. The reason is therefore obvious why a large aperture shows lines that are invisible with a small aperture. The relief of a bust, or of a relievo, either *basso* or *alto*, is best seen when we look at it in profile. Its height is then actually seen, whereas it is merely inferred when we look it full in the face. When the *raised* lines of a test-object are illuminated only obliquely, they are seen obliquely, and consequently much better than with a small aperture, which may not show them at all; not because the object-glass is inferior in penetrating power, but because the thing looked at in the one case is not the thing looked at in the other, and is actually a smaller object.

Errors of large angular apertures.

Hence the perfection of a microscope consists in its having the smallest angular aperture consistent with distinct vision. Such a microscope will not show certain objects of great minuteness, but it will give a perfect representation of what it does show. The large angular aperture will show the same objects, and others far more minute, but whatever it does show will be a mockery of the truth.

Admitting the truth of these observations, it follows that an observer who examines a microscopic structure in relief, and executes a correct drawing of it with an object-glass of *large* aperture and an eye-piece of *small* magnifying power, will obtain a very different and a much more correct drawing if, with the same magnifying power, he uses an object-glass of a *less* focal length of *small* aperture, and an eye-piece of a high magnifying power.

In the use of high magnifying powers obtained by object-glasses of short focal length we encounter another evil, well known to every microscopical observer. We can see only at one instant the parts of the object which are in the same focal plane, and by a fresh adjustment we see in succession the parts in other planes nearer to or farther from the object-glass.

New form of the microscope.

We are thus led to a new form of the microscope, in which object-glasses of large angular aperture should not be employed. In place of observing the object with such object-glasses, observe an image of the object formed with another achromatic object-glass with a proper angular aperture. This image may be the exact size of the object as produced by placing the object at a distance equal to twice its focal length, or it may be made greater by diminishing that distance, or less by increasing it. In all these cases the distance of the object from the first lens is so great that opaque objects may be illuminated by a Lieberkhun, or any method that may be preferred, and large objects may be submitted to examination to which the microscope in its present form cannot be applied. When the angular aperture is large, and the magnifying power great, the object approaches so near to the lens that the microscope becomes quite unfit for important physiological researches. It is unfit also for all researches in which experiments require to be made upon the objects under examination, for the examination of objects inclosed in minerals or other transparent bodies, and for objects in which there is any distance between their near and remote parts.

Mr. Pritchard's list of test-objects.

The following is the list of test-objects given by Mr Pritchard, and arranged in relation to *penetrating* and *defining* power,—a distinction which the preceding observations justify us in preserving; the word *penetrating* meaning nothing more than the effect produced by angular aperture:—

I.—PENETRATING POWER.

SECT. I. *Easy.*
1. Petrobius maritimus, scales of.
2. Lepisma saccharina, scales of.

SECT. II. *Standard.*
1. Morpho Menelaus, feathers of.
2. Alacita pentadactyla, feathers of the.
3. Alacita hexadactyla, feathers from the body of it.
4. Lycænæ Argus, feathers of the.
5. Tinea vestianella, or clothes-moth, feathers from under ends of the wing.

SECT. III. *Difficult.*
1. Pieris or Pontia brassica, or cabbage-butterfly, feathers from the.
2. Podura plumbea, scales from the.

II.—DEFINING POWER.

1. Hair of the common mouse.
2. Hair of the bat genus.
3. Leaf of the moss Hypnum, species unknown.
4. Spotted scales of the Lycænæ Argus.

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[1] Brewster's *Optics*, chap. vii., p. 65, edit. of 1853.

Since the publication of Mr Pritchard's *Micrographia* the microscope has undergone great improvements, and the structure of test-objects has been more successfully examined. Mr Quekett, in his treatise of 1848, has given the following list of test-objects as furnished by Mr Topping:[1]—

Hairs.

Bat.
Larva of Dermestes.
Mole.
Mouse.
Rabbit.
Squirrel.

Scales.

Azure blue, P. argiolus.
... P. Argus.
Pontia brassica.
Vanessa Io.
Morpho Menelaus.
Alacita pentadactyla.
Catocala nupta.

Scales.

Tinea vestianella.
Lepisma saccharina.
Podura plumbea.
... aquatica.
Hipparchia janira.
Plumed gnat.

Infusoriæ.

Navicula hippocampus.
... Spenceri.
... angulata (Humber.)
... ... (America.)
Tripoli from Kritchelberg.

Muscular fibre.

From each class of these test-objects Mr Quekett has selected a certain number, and given in four plates highly-magnified representations of them, which exhibit great skill in the engraver, and still more in the artist, Mr Leonards. The magnifying power employed was sometimes 2000 diameters.

Plate of test-objects.

Very fine drawings of test-objects have been recently made by Dr Griffith, one of the able authors of the *Micrographic Dictionary.* Those drawings, which we have been kindly permitted to copy, occupy the first eighteen figures of Plate XX. We have added to these figures a few from Mr Quekett's practical *Treatise on the Microscope*,[2] the best work on the subject which has appeared in our language.

The following is a particular description of Plate XX:—

Fig. 1. The hairs of the larva of *Dermestes lardarius*, placed in Canada balsam.
2. Hairs of the common bat (*Vespertilio pipistrellus*), in balsam. *a*, *b*, coloured hairs; *c*, a white hair.
3. Hairs of mouse (*Mus domesticus*), in balsam.
4. Pits of coniferous wood, common deal (*Abies excelsa*), viewed dry.
5. Mucus (or salivary corpuscles), seen with different powers.
6. Scales of *Lepisma saccharina*, dry.
7. Scale from the wing of *Morpho Menelaus*, dry.
8. Scale from under side of wing of common clothes-moth (*Tinea vestianella*), dry.
9. Scales of *Hipparchia janira*: *a*, dry, and by oblique light; *b*, in balsam, by direct light; *c*, dry, after Schacht.
10. *Didymohelix ferruginea*, under different powers: *b*, with imperfect adjustment; *c*, with perfect adjustment; *d*, separate fibres.
11. *Didymoprium Borreri*, empty cells.
12. Scales of *Podura plumbea* under different powers: *a*, 220 diameters.
13. *Pygidium of flea.*
14. Frustule of *Grammatophora marina*: *a*, front view; *b*, side view.
15. Frustule of *Grammatophora subtilissima*: *a*, front view; *b*, side view.
16. *Gyrosigma angulatum*; dry valve showing the dots.
17. *Gyrosigma attenuatum*; dry valve showing the lines.
18. *Gyrosigma elongatum*; dry valve showing the lines.

The following ten figures are from Mr Quekett's plates:—

19. Hair of a species of bat from India.
20. *a*, Large scale from *Podura plumbea*; *b*, the same magnified 1250 diameters.
21. *Navicula Spenceri* as drawn by Mr Warren de la Rue, magnified 1900 diameters. Mr Spencer saw lines only with the power of 800; M. de la Rue saw the dots as holes or depressions.
22. *Navicula angulata*: *a*, magnified 1200 diameters; *b*, magnified 2000 diameters.
23. Ultimate fibrillæ of muscular fibre. Their true structure is shown in *b*, *d*, *f*.
24. Scale from the wing of the male *Pontia brassica*, dry.
25. Portion of wing of *Pontia brassica*, showing the imbrication of the scales.
26. Portion of valve of *Gyrosigma strigosum*, magnified 1800 and 4700 diameters.

The following observations, showing the relation between the magnifying powers and angles of apertures of English microscopes, and the objects most useful for testing object-glasses, have been given by Dr Griffith and Professor Henfrey.[1] The magnifying power is given in diameters:—

1. *Object-glass* $1\frac{1}{2}$ *or* 2 *Inches.*—Magnifying power, 20; aperture, 12° to 20°. *Test-objects:* The pygidium of the flea, Plate XX., fig. 13, *a*—the outline and the hairs should be distinct; the hair of the mouse, fig. 3.
2. 1-*Inch or* $\frac{2}{3}$*ds Object-glass.*—Magnifying power, 60; aperture, 22° to 27°. *Tests:* Hair of Dermestes, fig. 1; of bat, fig. 2; the pygidium of the flea, the outline of the areolæ being distinguishable under the high eye-piece with power 120 to 200, but not the rays.
3. $\frac{1}{2}$-*Inch or* $\frac{4}{10}$*th-Inch Object-glass.*—Magnifying power, 100 to 200; aperture, 55°. *Tests:* Hairs, figs. 1, 2, 3; disks on deal, fig. 4; the coarser scales of Lepisma, fig. 6, *a*; the pygidium of the flea, fig. 13, *a*, *b*, the entire structure being visible with the high eye-piece; a dark scale of Podura, fig. 12, *a*.
4. $\frac{1}{4}$*th-Inch Object-glass.*—Magnifying power, 220; aperture, 75° to 140°. *Tests:* The hair of Dermestes; disks of deal; salivary corpuscles, fig. 5, the moving molecules being clearly distinguishable; the smaller scales of Lepisma, fig. 6, *a*, *b*; the scales of Podura; filaments of Didymohelix, fig. 10, *a*; the pygidium of the flea, and the scales of Pontia brassica, fig. 26.
5. $\frac{1}{8}$*th-Inch Object-glass.*—Magnifying power, 420 to 450; aperture, 110° to 150°. *Tests:* The paler scales of Podura; the pygidium of the flea; the scales of Pontia brassica; the filaments of Didymohelix, showing the component fibres; the salivary corpuscles.
6. $\frac{1}{12}$*th or* $\frac{1}{16}$*th-Inch Object-glass.*—Magnifying power, 600 to 650; angular aperture, 80° to 120°. *Tests:* The paler scales of Podura; the filaments of Didymohelix, mounted in balsam; and the ultimate fibrillæ of muscular fibre, fig. 27.

Different writers have proposed different objects for testing microscopes. The test employed by Professor Amici is the exhibition of the lines on the *Navicula gracilis*, which the writer of this saw beautifully displayed by the professor himself. It is a good test for angular apertures.

Mohl uses the scales of *Hipparchia janira* for testing penetrating power; and pollen grains, the scaly elytra of the diamond beetle, or bat's hair, for testing definition.

Nobert's test-lines.

The most perfect of all tests are the test-lines of M. Nobert of Barth in Prussia.[2] These tests consist of ten separate bands of parallel lines, traced upon glass with the point of a diamond, the lines being drawn closer and closer to each other, from No. I., where they are widest, to No. X., where they are closest, varying, as shown in the following table, from the 11,000th to the 50,000th of an inch:—

	Thousandths of an English inch.		Thousandths of an English inch.
No. I.	11,265	No. VI.	24,309
II.	13,142	VII.	28,433
III.	15,332	VIII.	33,153
IV.	17,873	IX.	38,613
V.	20,853	X.	49,910

All these bands are engraven on the same plates of glass; and when seen by the naked eye they appear like the small black line *mn* in the annexed fig., ABCD being the size of the plates of glass on which they are engraven.

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[1] New Winchester Street, Pentonville. Mr Norman, Fountain Place, City Road, also supplies excellent sets of test objects.

[2] This work forms vol. vi. of Mr Bailliere's *Library of Illustrated Standard Scientific Works*, a collection of treatises of very rare merit.

[1] *Micrographic Dictionary*, art. *Test Objects*, p. 636, 637.

[2] See *Poggendorff's Annalen der Physik*, 1846.

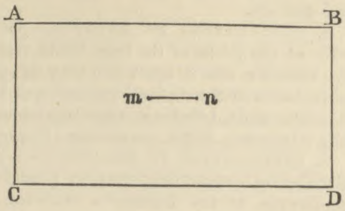

Fig. 100.

The subdivision of an inch has been more recently carried farther by M. Nobert. In a plate of fifteen bands the lines amount to *fifty-six thousand* in an inch. The following table, calculated by Mr Warren de la Rue, shows not only the number of the lines, but their distance also, in parts of an English inch:—

	Distances.	Number of Lines.
No. I.	0·00008880	11261
II.	0·00007548	13248
III.	0·00006482	15427
IV.	0·00005506	18162
V.	0·00004884	20475
VI.	0·00004202	23463
VII.	0·00003552	28153
VIII.	0·00003108	32175
IX.	0·00002664	37537
X.	0·00002442	40950
XI.	0·00002220	45045
XII.	0·00002113	47326
XIII.	0·00001998	50056
XIV.	0·00001891	52882
XV.	0·00001776	56306

The resolution of these lines is regarded as the best test for angular aperture and oblique light. Dr Griffith states that even the group of the 60,000 (56,306 in the above table) can be resolved by the ⅛th of an inch object-glass, and he considered the resolution of it "much easier than that of the markings upon the valves of many of the Diatomaceæ." A considerable difference of opinion exists respecting the magnifying power necessary to resolve different groups of these lines.[1]

CHAPTER XII.

ON MICROSCOPIC OBJECTS.

Microscopic objects.

In the preceding chapter we have already described some of the most interesting objects for microscopical observation. Every department of nature is full of objects, from the examination of which the most important discoveries may be expected; but though the zealous observer can never be at any loss for subjects of research, it is desirable to know what has been done by our predecessors, and what trains of inquiry are most likely to prove of general interest. There are subjects of microscopic inquiry which are closely connected with the most interesting parts of physiology; and even geology itself, conversant with the grandest subjects of research, has recently been illustrated by the aid of the microscope.

Ehrenberg's discoveries.

Dr Ehrenberg of Berlin, to whom we are indebted for so many important discoveries respecting the organization of infusorial animalcules,[2] has made the most remarkable discovery of *infusorial organic remains*. These remains are the siliceous shells of animalcules belonging to the division Bacillaria, and form strata of tripoli, or polischiefer (polishing-slate), at Franzenbad in Bohemia.[3] M. Ehrenberg has more recently discovered them in the semi-opal found along with the polishing-slate in the tertiary strata of Bilin, in the chalk flints, and even in the semi-opal or noble opal of the porphyritic rocks.[1] The size of a single individual of these animals is about $\frac{1}{288}$th of a line, or $\frac{1}{3456}$th of an inch. In the polishing-slate from Bilin, in which there appear to be no vacuities, *a cubic line* contains, in round numbers, 23,000,000 of these animals, and *a cubic inch* contains 41,000,000,000 of them!

The weight of a cubic inch of the polishing-slate is 270 grains. There are therefore 187,000,000 of these animals in a single grain, or the siliceous coat of one of these animals weighs the 187,000,000th part of a grain!

In the annexed figure we have given representations of these singular microscopic objects, as seen by Ehrenberg. The siliceous shells found in the Franzenbad poli-schiefer are much more distinct than those found in the Bilin strata.

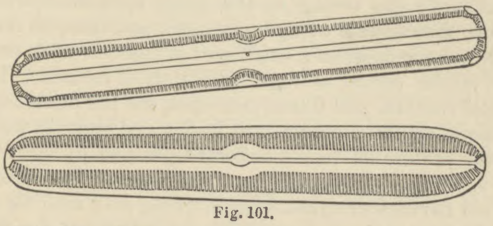

Fig. 101.

Fibres of the crystalline lenses of fishes.

Another example of the value of microscopical observations may be drawn from the discovery of the teeth of the fibres which compose the crystalline lenses of almost all animals. The crystalline lens is composed of innumerable fibres of nearly the same length, each of which tapers from its middle to its two extremities, where it comes to the sharpest point. The sides of each of these fibres are furnished with teeth like those of a watch-wheel, and the teeth of the one lock into those of the adjacent ones, as shown in the annexed figure. When the power is small, or the microscope not good, or the laminæ too thick, and not nicely detached, each row of interlocking teeth appears as a dark line, sometimes as sharp as a black line drawn upon paper with a pen. Sometimes the lines appear rough and ragged; and as the fibres become less and less in approaching the poles, the black lines are as difficult to resolve into teeth as the lines on test-objects already described. The following measures, taken by Sir David Brewster, will show what a wonderful structure in the eye has been thus disclosed to us by the microscope. The calculations refer to the lens of a cod, 4-10ths of an inch in diameter:—

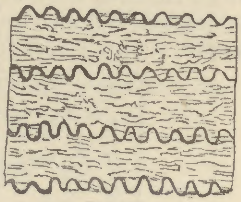

Fig. 102.

Number of fibres in each lamina or spherical coat	2,500
,, teeth in each fibre	12,500
,, teeth in each spherical coat	31,250,000
,, fibres in the whole lens	5,000,000
,, teeth in the lens	62,500,000,000

or the lens of a cod contains five millions of fibres and sixty-two thousand five hundred millions of teeth; and if we reckon the curved end of the tooth as one surface, each tooth will have six surfaces,[2] which come into contact with the corresponding surfaces of the adjacent tooth, so that the number of touching surfaces will be *three hundred and seventy-five thousand millions*;[3] "and yet this little sphere of tender jelly is as transparent as a drop of the purest water, and allows a beam of light to pass across these almost innumerable joints without obstructing or reflecting a single ray!"

There is another class of objects of extreme interest,

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[1] See Lardner on the Microscope, p. 67 and 72; and the reports by the juries of the Great Exhibition, p. 208.

[2] *Organization Systematik der Infusions Thierchen*, 3 vols. folio., Berlin, 1830-1834, and *Microgeologie das Erden und Felsen Schaffende Wirken des unsichtbar kleinen selbstandigen Lebens auf der Erde*, von Christien Gottfried Ehrenberg, 1 vol. folio., with 40 folio plates.

[3] Poggendorff's *Annalen der Physik*, 1836, No. V., p. 225.

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[1] Poggendorff's *Annalen der Physik*, No. VI., 464.

[2] This includes the concave surface between two adjacent teeth.

[3] *Philosophical Transactions*, 1833, p. 329.

Microscopic cavities in minerals.

which Mr Pritchard and other writers have omitted to notice, and the development of which calls forth all the resources of optical knowledge and optical experience with the microscope. These objects are the microscopic cavities in minerals, containing two fluids unknown to the chemist; groups of crystals of different forms, and floating balls, and exhibiting actual chemical operations going on in these minute laboratories when exposed to changes of temperature. These various phenomena have been described and represented in drawings, in two papers by Sir David Brewster published in the *Transactions of the Royal Society of Edinburgh*.[1] In some of the precious stones, particularly in diamond, garnet, &c., these cavities are perfect spheres; but owing to the great refractive power of the gem, they appear completely black and opaque, though the microscope descries a small spot of light in their centre, which is the pencil of light which they refract. These spherical cavities, and this central spot, are the finest objects for examining the aberration of lenses and specula, and are infinitely preferable to the reflected patches of light from small spherules of quicksilver. Dr Goring has observed spherical cavities or air-bubbles in fluids, and, with his usual ingenuity, recognised their utility for indicating the effects of aberration. Those which we have used in the gems are, however, permanent instruments of much greater utility, not only from our being able to use the same bright spot with all instruments and on all occasions, but from the dark ring round the bright spot being incomparably greater in the gems than in fluids.[2] Representations of some of the cavities containing the two new fluids, which will not mix, though in the same cavity, are given in fig. 103. The little white circle is the bubble either of gas or of vacuity. The fluid round it, shown by dots, is a highly evaporable fluid, and the fluid in the angles and ends of the long cavities, shown by the shading, is a thick and unevaporable fluid, which indurates when exposed to the air. These cavities lie in strata, and millions of them, which no microscope can resolve, occupy a very small area.

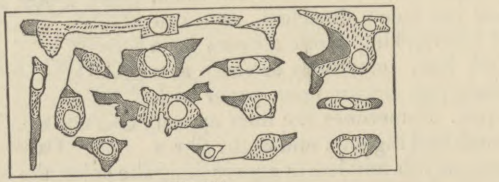

Fig. 103.

List of microscopic objects.

Our limits will not permit us to pursue this subject further, and we shall conclude the article with a very brief selection of microscopic objects from Mr Pritchard's admirable little pamphlet, entitled *A List of Two Thousand Microscopic Objects.*

1. Insects (eggs, wings, tongues, antennæ, and scales of).
   Eyes of Agrion, 12,000 eyes; Bombyx mer, 6236 eyes; Phalæna cossus, 11,300; Scarabæus, 3180; Hawk-moth, 20,000; Libellula, 12,544; Melalontha, 8820; Mordella, 25,088; Papilio, 17,000.

2. Hairs of Animals.—Hair of an infant, Ornithorynchus, mouse, bat, bee, Acilius canaliculatus, Melecta punctatus, Siberian fox, spider, wing of Tipalis, stag-beetle, white cat, dormouse, dermestes, caterpillar, badger, ant-eater, civet cat.

3. Sçales of Insects.—Podura plumbea, Pontia brassica, Pieris brassica, Parnassus Apollo, Atlas moth, diamond-beetle, Euplœa limniacæ, house-moth, Lepisma saccharina, 10-plumed moth, 20-plumed moth, Morpho Menelaus, Papilio Apollo, Papilio Paris, Urania leilus, privet-moth.

4. Circulation in Plants, or *Cyclosis*.—Nitella hyalina, Nitella translucens, Chara vulgaris, Caulinia frigalis, Hydrocharis or frogbit in the stipulæ of the leaves and the ends of the roots, Tradescantia virginica or spiderwort in the filaments around the stamina, Senecio vulgaris or groundsel in the hairs surrounding the stalks and flowers.

5. Circulation in Animals.—In the arachnoidæ or spider tribe at the joints of the legs, Peria viridis and Semblis bilineata on the antennæ and wings when they have just emerged from the chrysalis, larva of the Ephemera, larva of Hydrophilus, small Dysticus, Agrion puella, Libellula, round Lynceus, fresh-water shrimp, water-hog (Oniscus), Ligia, water-flea (Daphnia pulex).

6. Circulation in Zoophytes.—Mr Lister has discovered a circulation resembling that in plants in some of the polypiferous zoophytes, as the Tabularia indivisa, Sertulariæ, Campanulariæ, Plumulariæ, &c.

7. Crystals.—For an account of various interesting microscopic phenomena observed by H. F. Talbot, Esq. of Lacock Abbey, we must refer the reader to a series of papers in the recent numbers of the *London and Edinburgh Philosophical Magazine*, and to others which will be found in the *Philosophical Transactions*.

The oxalate of chromium and potash dissolved in water, and rapidly crystallized, is a fine object. In polarized light a very splendid object is the Faro apophyllite, when the prisms are complete, as represented by Sir David Brewster in a coloured drawing in the *Edinburgh Transactions*, vol. ix., p. 317, plate xxi., fig. 1. But the most beautiful of all objects, as seen by polarized light, are the circular crystals, first described by Mr Talbot, as produced by a peculiar process. In a recent paper "On Circular Crystals," by Sir David Brewster,[1] no fewer than about eight circular crystals have been described, with twenty-five coloured drawings of the most interesting. Several of these are to be found in the slides sold by the preparers of microscopic objects.

8. Animalcules:—

Monas Termo, 18,000th of an inch.
Monus atomus, 4000th of an inch.
Monas volvox, 3456th to 1728th of an inch.
Volvox globator, found in stagnant water, 30th of an inch.
Vibrio bipunctatus, 200th of an inch.
Vibrio spirillum, like a screw, 2000th to 1000th of an inch.
Vibrio glutinis.[2]
Kolpoda cucullus, 28th of an inch.
Cercaria podura.
Cercaria viridis.
Cercaria hirta.
Leucophrys fluida, 400th of an inch.
Trichoda vulgaris, 1200th to 240th of an inch.
Trichoda longicauda.
Vorticella polymorpha.
Vorticella convallaria.
Vorticella senta, 100th of an inch.
Vorticella rotatoria.[3]

References to works on microscopic objects.

The reader will find beautiful drawings and full descriptions of these and many other animalcules in Mr Pritchard's interesting work entitled *The Natural History of Animalcules*, London 1834; in the *Microscopical Illustrations* of Mr Pritchard and Dr Goring; and in the *Microscopic Cabinet* by the same authors he will find much information respecting microscopic objects.

In the more recent work of Ehrenberg, Quekett, and Lardner, already cited; in Pritchard's large work recently published, entitled *A History of Infusorial Animalcules, Living and Fossil*, illustrated with 24 plates; and in Dr Griffith and Professor Henfrey's *Micrographic Dictionary*, the reader will find everything that he desires. This last work is illustrated with no fewer than 41 engravings and coloured plates, and with 816 wood-cuts admirably executed; and owing to these illustrations and its alphabetical arrangement, the general reader will find in it a store of easily-accessible and popular information, apart from its science, which cannot fail to amuse and instruct him. (D. B.)

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[1] See *Edinburgh Transactions*, 1823 and 1826, vol. x., pp. 1, 407; vol. xv., pp. 7, 11.

[2] The ratio between the diameter of the dark sphere and of the small luminous spot gives a measure of the refractive power of the solid or fluid.

[1] *Edinburgh Transactions*, 1853, vol. xx., p. 607.

[2] Figured by Dr Goring in the *Microscopic Cabinet*.

[3] The *Rotifer vulgaris*. See *Microscopic Cabinet*, chap. vi., p. 58-69; and *Pritchard's Nat. Hist. of Animalcules*, p. 167. The reader will find a very interesting discussion of the apparent rotatory movements of the wheels of this extraordinary animalcule, by Mr Faraday, in the *Journal of the Royal Institution*, vol. i., New Series, p. 220; October 1830, May 1831. See also Baker, *Of Microscopes*, vol. ii., p. 266-295; Adams *On the Microscope*, pp. 548; and Leuwenhoeck in the *Phil. Trans.*, No. 283, 295, 337.

MIDAS, in Greek mythology, a king of Phrygia, was the son of Gordius, and, according to some authorities, of Cybele. He seems to have been a disciple of Orpheus; and, like him, a worshipper of Dionysus. When that deity was passing through Phrygia, on his way from Thrace, Silenus, who accompanied him, having become intoxicated, was found in the gardens of Midas, and brought before the king, who received him hospitably, and sent him back to Dionysus. In return for this, the god desired Midas to ask whatever favour he wished. He accordingly requested that he might have the power of turning whatever he touched into gold. This favour was granted; but Midas finding that he ran the risk of being starved, from his food and drink being changed into gold, he begged the god to recall his gift. He was accordingly directed to wash in the river Pactolus, which ever after had gold in great abundance among its sands. Another legend of Midas is, that having been appointed judge in a musical contest between Apollo and Pan, he decided in favour of the latter; whereupon Apollo in revenge gave him the ears of an ass. These Midas endeavoured to conceal under his cap, but was obliged to disclose the disagreeable fact to his barber, who being bound to secresy, and yet unable to keep his discovery to himself, dug a hole in the earth, and having whispered into it the singular intelligence, closed it up again. But there seemed to be a fate in it, for the very seeds which grew from the spot murmured in a low tone as they rustled in the wind, "King Midas has the ears of an ass;" and thus disclosed to the world the deformity and disgrace of the monarch. Midas seems to have been a common title of the reigning dynasty in Phrygia; and a king of that name is mentioned by Herodotus as having sent offerings to the temple of Apollo at Delphi.

MIDDLEBURG, a town of Holland, capital of the province of Zealand, is situated near the centre of the island of Walcheren, 4 miles N.E. of Flushing. It is surrounded by a bastioned mound of earth and by a broad and deep ditch. It is partly intersected by canals, and has a small harbour, being connected with the West Scheldt by a canal. The town is generally well built, and has wide and regular streets. Among the public buildings are—the town-house, an elegant Gothic building; St Peter's church and the Abbey church, both containing fine paintings and monuments; a Jewish synagogue; and an exchange. Its institutions comprise an athenæum, Latin school, school of design, museum, public library, and agricultural society. The manufactures, including starch, glass, paper, salt, &c., are considerable; and an active import trade in wine, and export trade in corn, is carried on. Pop. (1855) 16,253.

MIDDLESBOROUGH, a town and river-port of England, in the North Riding of Yorkshire, on the River Tees, not far from its mouth, and about 3 miles E.N.E. of Stockton, with which it is connected by railway. Little more than twenty years ago the site of Middlesborough was occupied by a solitary farm-house. It is now the most considerable port on the Tees, though still reckoned as subordinate to Stockton. It owes its rise chiefly to its convenient situation as a port for the shipment of coals. There are commodious docks, ship-building yards, foundries, rope-walks, sail-cloth manufactories, ironworks, &c. The church of St Hilda, erected in 1840, is an elegant Gothic structure surmounted by a spire. There is also a national school, observatory, reading-room, mechanics' institute, and savings-bank. Pop. (1851) 7431.

MIDDLESEX, the metropolitan county of England, the smallest in size, with the exception of Rutland, and the greatest in density of population, wealth, and importance. London, the capital of England is situated in its S.E. corner. The county is bounded on the N. by Hertfordshire, on the E. by Essex, on the S.E. by Kent, on the S. by Surrey, and on the W. by Buckinghamshire. The eastern boundary is formed by the River Lea, the southern by the Thames, and the western by the Colne. The shape of the county is very irregular: in the N.E. a spur of Herts penetrates deeply within its boundaries, and on the S.W. a large portion of the county projects into Surrey. The greatest length of the county is from near Waltham Abbey in the N.E. to Chertsey in the S.W., 28 miles; and its greatest breadth from near Rickmansworth in the N.W. to the Isle of Dogs in the S.E., 17 miles. The area of the county is 180,168 statute acres, or about 282 square miles.

The surface of the county is a sloping plain, bounded by a range of hills about 400 feet high: these hills partly form its northern boundary. There are some gentle undulations of the ground, of which Hampstead is one; but the general aspect of the county is flat, and would be monotonous if it were not diversified by buildings, gardens, and the rich verdure which high cultivation imparts to vegetation. Neither is the landscape picturesque, as seen from the hills; but the most pleasing view is obtained at Harrow, an insulated hill overlooking the whole county, and the seat of the famous seminary.

The county is entirely situated within the basin of the Thames. The substratum consists of the blue clay known as London clay, lying in the great chalk basin extending from Berkshire to the east coast, and it varies in thickness from 40 to 240 feet. The only exceptions to this formation are at Uxbridge, on the western boundary, and at Enfield, in the N.E. corner of the county, where the plastic clay crops out. The hills consist of sand and gravel, and have been formed by the sea. The soil in the northern part of the county is a clayey loam, difficult to plough, and indeed altogether unfit for cultivation until chalk, lime, and ashes have been incorporated with it; and in the southern part it is formed by gravel, which is naturally very sterile, but which, being enriched by the vast quantities of manure afforded by London, is converted into a garden mould of prodigious fertility. The soil is generally dry; and the temperature being raised by the chimneys of London, the climate is remarkably healthy.

The rivers of the county are,—the Cray, the Colne, the Brent, the Lea, and the Thames. The Cray rises within the county, near Harrow, and, after a very eccentric course of twenty miles, falls into the Thames at Isleworth. The Colne enters the county from Herts, near Rickmansworth, and flows by Watford, Harefield, Uxbridge, and Colnbrook, throwing off several branches; but the main stream falls into the Thames at Staines. The length of its course within the county is 18 miles. This river, though small and devoid of beauty, is sacred to the admirers of genius, for on its banks Milton lived and composed some of his great poems. The Lea enters the county from Essex at Walthamstow, and flows by Stamford Hill, Tottenham, Bow, and Bromley, into the Thames at Limehouse, after a course of about 18 miles within the county. The first stone bridge built in England stood on the river at Stratford-le-Bow, and its curved form gave the village its familiar name of Bow. The Brent rises on the northern boundary of the county, near Monken-Hadley, and flows through its centre, by Finchley, Hendon, Kingsbury, Twyford, and Hanwell, to Brentford in the W., and after a course of 20 miles falls into the Thames. The Cray and the Colne are not navigable. The lower part of the Brent forms a portion of the Grand Junction Canal; and the Lea is rendered navigable by a series of artificial cuts. The Thames, "great father of the British floods," enters Middlesex a sylvan river. It reaches the county at Staines, and flows by Shepperton, Kew, and Kingston, in many a mazy fold to London, and here it joins the sea. The length of its course within the county is about 15 miles. The Thames is rendered navigable for barges within a short distance of its sources in Gloucestershire by a series of locks and weirs, the lowest of which is at Teddington, within the county, where the tide is felt at high water. The Thames is crossed by 13 bridges below this point, viz., Richmond, Kew, Hammersmith, Putney, Battersea, Chelsea, Vauxhall, Westminster, Hungerford, Waterloo, Blackfriars, Southwark, and London bridges; and there is also a communication between the opposite banks by a tunnel carried under the bed of the river, 2 miles below London Bridge, and in the centre of the shipping. The port of London, consisting of the upper, middle, and lower port, lies between London Bridge and Limehouse; but for legal purposes it is extended for 6½ miles below the bridge to a point beyond Blackwall called Bugsby's Hole. Other articles in this work render it unnecessary to describe here the vast population, the features, and operations of the great and wonderful city which lies stretched along the banks of the Thames for 7 miles, the lines of wharfs, the capacious docks, the gigantic warehouses, the cellars, measured in acres, the dockyards, the defences, the public establishments, and all the other wonders of what, to use the words of M. Say, " is no longer a city, but a province covered with houses." (See LONDON.)

The facilities of inland navigation which the Thames and the Lea afford are increased by two canals, which conjointly traverse the county from end to end. The chief is the Grand Junction Canal, opening out of the Thames at Brentford, and passing by Crayford, Hanwell, West Drayton, and Uxbridge, from whence it enters Herts, and ultimately communicates with the Irish Sea. At Crayford this canal throws off a branch which passes by Twyford to Paddington, and there it joins the Regent's Park Canal, which traverses Camden Town, Islington, Hackney, Mile-end, and communicates with the Thames at Limehouse. The most remarkable artificial water-course in the county is the New River, constructed by Sir Hugh Myddleton to convey pure water into the city of London. He chose for the fountain-head some springs of water, very copious and beautifully clear, at Ware in Herts; and from thence carried to London, through hills and deep cuttings, over valleys in wooden troughs, and by a serpentine channel 37 miles long, a stream of pure water on the average 24 feet wide, 4 deep, and flowing with a fall of 3 feet per mile. The New River was completed five and a half years after its commencement, and was put in operation with much ceremony, on the 29th of September 1613. The stream has since been enlarged by adding to it some of the water of the River Lea, which runs parallel to its course, and close to its banks at some points, and two large purifying reservoirs have been constructed at Stoke-Newington.

The county is completely intersected by railways issuing out of the metropolis. The London and North-Western Railway traverses it from the Isle of Dogs, passing by Camden Town, Kilburn, Willesden, Sudbury, Harrow, and Pinner, into Hertfordshire near Watford; the Great Northern Railway, from King's Cross, by Holloway, Hornsey, and Barnet, passing into Herts near Hatfield; the Eastern Counties Railway, from Shoreditch, by Stratford-le-Bow, Leabridge, Tottenham, and Enfield, and also passing into Herts near Waltham Cross; the Great Western Railway, from Paddington, passing by Ealing, Hanwell, Southall, West Drayton, and Uxbridge, into Buckinghamshire; and the London and South-Western Railway, which crosses the Thames from the Surrey side of the metropolis at Barnes, and passes by Kew, Brentford, Isleworth, Hounslow, and Staines, also into Bucks. These lines are linked together by branches; and it may be added that several other railways connect the Surrey side of the metropolis with the eastern and southern coasts.

Middlesex possesses no agricultural importance, its cultivated land being the mere fringe of a great metropolis. That part of it which is not encumbered with buildings and ornamental grounds is mainly converted into gardens and grass lands. Spade husbandry and an abundant application of manure compensate for the natural sterility of the soil; the ground is converted into a hotbed, and crop after crop is obtained without intermission, yet without exhausting the soil. Two, and sometimes even three crops are grown at once: an upper crop, as it is called, consisting of apples, cherries, pears, plums, and walnuts; an under crop, consisting of currants, gooseberries, raspberries, strawberries, and other fruit which will thrive in the shade uninjured by the dripping of trees; and a third crop, consisting of esculent vegetables, placed between the other two. The garden walls are also clothed with fruit trees adapted to the aspect they present, such as apricots, nectarines, peaches, and plums. The ground is also sometimes raised in banks sloping to the sun, in order to give it increased warmth and shelter in autumn, and thereby augment its productiveness. In short, by continual manuring, stirring, and moving the soil, sterility is replaced by fertility, crops succeed each other without a moment's respite, and a garden of 10 acres is rendered as profitable as a farm ten times that size.

The extent of the farms averages about 100 acres, the majority of them being below that area; and rents average 40s. an acre. A skilfully managed farm at Willesden, consisting of 100 acres of grass land, is let at 60s. an acre; the tenant paying besides 15s. an acre for tithes and taxes. White and green crops are grown alternately; but the rotation is so irregular that no general description can be given. The arable land, when thoroughly pulverized, produces wheat of good quality. Potatoes are not so much grown as might have been expected, considering the almost insatiable demand of the metropolis; distant counties, in which rent is lower and labour not so highly paid, being enabled by superior cheapness to monopolize the market. Haymaking in this county is not the simple operation which it is in other counties. The grass is constantly shaken, moved, and exposed to the action of sun and wind, by the aid of machines and a large number of labourers; thus, the quality is heightened, and when cut out of the mow, the hay exhibits a bright green colour. The spring crop averages 2 tons per acre, and the aftermath about half that quantity. The farm at Willesden, already noticed, produced no less than 6 tons per acre, there being nine cuttings in the year. The grass lands of the county are generally well manured after the first mowing, and provided with water-furrows when the closeness of the soil renders it impervious. Under-draining is, however, much neglected, and in consequence the clay land is so wet that stock cannot safely be put on it after October. On the whole, Middlesex is backward as regards farming; in common, however, with the adjacent counties. " The state of agriculture which prevails in the surrounding counties," says M. Lavargne, "makes itself felt up to the very gates of the greatest existing centre of consumption." But this may be said in explanation of the apparent anomaly, —that though the distance between the metropolis and the farms is small, the advantage is greatly diminished by the cost of bringing manure along crowded thoroughfares.

The clay soil itself in many parts of the county is turned into produce. *Breeze*, the technical term for cinders, is mixed with the clay, and the compound is baked into bricks, for which an enormous demand is created by the unceasing growth of the metropolis; and brickmaking is probably the most profitable mode of employing the soil. After the soil has been manufactured into buildings in this way, yielding from L.4000 to L.20,000 per acre, the excavations are levelled, ploughed, and manured, and the surface is converted into grass land.

Very few cattle are kept for farming purposes, as it is more profitable to buy manure, and in consequence root crops are not much grown. About 15,000 cows are, however, kept in London and its environs, for the supply of milk and cream. Though every kind of breed may be met with in the county, the short-horn or Holderness is preferred, because it yields the heaviest carcass to the butcher. The cows being highly fed, increase in weight while they continue to give milk, and when they become dry are fat and fit for market. Grass lands near London of course acquire a high value from the number of milch cows and horses kept to supply the wants of that great city; they are used for grazing as well as haymaking, thousands of over-worked horses being annually turned out to grass during the season.

The manufactures of the county are concentrated in the metropolis, which, however, is rather a great exchange than a seat of industry. The silk manufacture is extensively carried on in Bethnal Green, Spitalfields, and at Mile-end; sugar-refining in Whitechapel; and watch and clock-making in Clerkenwell; and there are large manufactures of shoes, cutlery, plate, printing-type, soap, spirits, vinegar, &c., which have no particular locality. A large number of ships is also built within the port of London. But the greatest manufacture of all, and the distinctive feature of the metropolis, is the brewing of the favourite beverages of the metropolitan population—ale and porter. The consumption of malt by the brewers within the London revenue district annually amounts to upwards of 6,000,000 quarters. It is estimated that 1,200,000 barrels, or 43,200,000 gallons of ale and porter are brewed for London consumption alone; besides a great quantity sent to other parts of the United Kingdom and exported to the Continent, the United States, and the East and West Indies. The principal brewers produce from 200,000 to 270,000 barrels a-year.

The county is divided into 6 hundreds, and 208 parishes, of which 118 are within the cities of London and Westminster. For ecclesiastical purposes, it forms part of the diocese of London, and is divided into the archdeaconries of London and Middlesex. The total number of places of worship in 1851 was 962, with 572,338 sittings. Of these 419, with 344,489 sittings, belonged to the Church of England; 155, with 84,514 sittings, to Independents; 102 to Baptists; 119 to Methodists; 32 to Roman Catholics; 16 to Mormons; and 9 to Jews. There were 3427 day schools; having 200,257 scholars, of whom 110,861 were males, and 89,396 females;—772 of these, with 138,108 scholars, were public day schools; and 2655, with 62,149 scholars, private day schools. Sunday schools 589, with 111,595 scholars. The county returns 2 members to parliament, the city of London 4, of Westminster 2, the three boroughs, 2 each; in all 14.

The population of the county was in 1821, 1,345,067; 1831, 1,358,330; 1841, 1,576,636; 1851, 1,886,576. The population of the cities, boroughs, market-towns, and other places was,—city of London, 127,869; city of Westminster, 241,611; borough of Marylebone, 370,957; borough of Finsbury, 323,772; borough of Tower Hamlets, 539,111; Brentford, 8870; Staines, 2430; Uxbridge, 3593. The number of houses in the county in 1851 was 251,236, of which 11,874 were building. The amount of real property rated to the property tax, was L.13,867,829. (F. C.)

MIDDLETON, Conyers, D.D., a celebrated English divine, was the son of the Rev. William Middleton, rector of Hinderwell in Yorkshire, and was born at Richmond on the 27th December 1683. At the age of seventeen he was admitted a pensioner of Trinity College, Cambridge, and after being chosen a scholar of his college, and gaining a bachelor's degree in 1702, he took deacon's orders, and exercised the clerical function for some time at Trumpington, near Cambridge. Having been elected a fellow of Trinity in 1706, he took the degree of M.A. during the following year; and in 1708 joined some of the fellows of his college in a petition to the Bishop of Ely, their visitor, against Bentley, the celebrated master of Trinity. Middleton did not at first take a very active part in this painful contest; yet the unpopular master soon saw in this strong, fiery youth one of his most dangerous enemies, and Bentley's partizans made an early attempt to blast his reputation. Such an attack only increased Middleton's popularity in the university, while it served to deepen his hostility towards the irascible and imperious scholar. After his marriage he held a small rectory in the Isle of Ely, in the gift of his wife, but was soon compelled, from the unhealthiness of the place, to return to Cambridge. Middleton, with a number of others, was created Doctor of Divinity by the royal mandate of George I., who visited Cambridge in 1717; but Bentley, who was regius professor of divinity at the time, would only grant the degree on terms by no means of a highly honourable kind. This gave rise to a fresh dispute between the two antagonists, in which Middleton gained a complete victory, and Bentley was degraded and deprived of his professorship. After "dragging the character of the fallen hero through three triumphant pamphlets," as a writer of the time phrases it, comparing the revenge to that of Achilles with Hector at his chariot wheels, Middleton found that he had established for himself a very considerable literary reputation. Whatever might be thought of the temper displayed in those productions, every one was ready to admit that in sprightly energy, scholarly elegance, and powerful invective, their author had few equals in England. Dr Monk remarks in his Life of Bentley that this production of Middleton's "was the first published specimen of a style, which for elegance, purity, and ease, yields to none in the whole compass of the English language. The acrimonious and resentful feeling which prompted every line is in some measure disguised by the pleasing language, the harmony of the periods, and the vein of scholarship which enliven the whole tract." Flushed with his pamphleteering success, and still thirsting for further revenge against his fallen enemy, he rushed into print for the fourth time with his accustomed intrepidity, when his zeal overcoming his discretion, his vigilant antagonist succeeded in proving him guilty of libel in the Court of King's Bench. The court, however, was unwilling to pronounce sentence, and Middleton escaped by begging Bentley's pardon and paying the expenses of the action. The arrogant master of Trinity had little reputation now left him but that of a great scholar and critic; and he resolved to present the public with a fresh testimony to his merits in a new edition of the Greek Testament. The proposals and specimens were drawn up, however, with too great precipitation; and Middleton, who doubtless submitted the matter to a minute scrutiny, succeeded in detecting not a few serious flaws in the production, and boldly assaulted this corypheus of critics in his last and greatest stronghold. This exposure ran through two successive pamphlets, characterized by all Middleton's accustomed power, and with an additional display of learning and critical sagacity for which no one, even among his friends, would have given him credit. But the virulent personal abuse was often of the lowest kind; and while disclaiming at the outset any personal spleen against his learned antagonist, it nevertheless soon became obvious that Middleton's former animosity had not yet been cooled down, and that he was prepared not only to strip Bentley of his reputation as a scholar, but also to rival him in that species of personal abuse in which the doctor of Trinity was so great a master.

The labour and expense to which Middleton had been subjected during those proceedings were regarded by his friends in the university as of such a public nature, and so much a vindication of the rights of their venerable institution, that they, by way of acknowledging his services, created the office of principal librarian, and conferred it upon him. His election met with much opposition, and his old enemy keeping close upon the watch, found Middleton speaking too freely in the dedication to his *Bibliothec. Ordinand. Method.*, respecting the jurisdiction of the King's Bench Court, for which he had him prosecuted and mulcted in L.50.

In 1724 Middleton was compelled, from declining health, to seek some milder climate, and accordingly visited Rome, where he spent about twelve months, collecting, among other objects of interest, materials for his future work on the *Paganism of the Popish Religion.* On returning to England in 1725, Middleton, from some personal pique against the celebrated physician Dr Mead, published an attack upon the whole medical profession, entitled *De Medicorum apud veteres Romanos degentium Conditione Dissertatio*, &c. It gave rise to much keen pamphlet-writing, and Middleton was not slow to reply. In 1729 he published one of his greatest works, and one which met with a large share of popularity among the learned. This was his celebrated *Letter from Rome, showing an exact conformity between Popery and Paganism*, &c., in which he attempted to show that the rites, ceremonies, &c., of the Romish Church were borrowed from the pagan religion. Notwithstanding the great power put forth on this book, in the way of solid argument and forcible writing, it was nevertheless the means, from its free attack upon the Romish miracles, of giving offence to not a few Protestant divines, who charged the author with a want of respect for the apostolic miracles. Nor was his anonymous letter to Dr Waterland in 1731, respecting his method of defending the Christian cause, calculated to remove the impression. On the contrary, the views respecting the partial inspiration of the Scriptures expressed in that work almost led to his being deprived of his situation and of his college honours. At this juncture he felt called upon to come publicly forward, and in *Some Remarks on a Reply to the Defence of the Letter to Dr Waterland*, &c., to disavow his alleged hostility to Christianity, and express emphatically his belief in that system. But these assertions were not sufficient to drown suspicion, and not a few of his reverend brethren were still inclined to regard him as an unbeliever. They could not get over his allegation that there were "contradictions in the four evangelists which could not be reconciled," or that the "story of the fall of man was a fable or allegory;" and his opinions thus proved an effectual barrier to his clerical promotion. His merits as a scholar, however, were never called in question, and in 1731 he was appointed to the chair of natural history, just founded by Dr Woodward,—a position which he held till his second marriage in 1734. He wrote during the subsequent year *A Dissertation concerning the Origin of Printing in England;* and in 1741 appeared his greatest work, *The History of the Life of M. Tullius Cicero*, written at the request of Lord Harvey, and published by subscription. He spent six years on this cherished task, and it met with great encouragement. The subscribers amounted to 3000, and the profits arising from the sale of the work enabled him to purchase a small estate at Hildersham, near Cambridge, where he spent the rest of his life. This work, while written with singular elegance and perspicuity, has been accused of partiality, in making too much of the great Roman. Middleton has, besides, been accused by Dr Parr, the editor of Bellendenus, of having borrowed largely in his *Life of Cicero* from the *De Tribus Luminibus Romanorum* of that eminent writer. Middleton's next publication was a translation of *Cicero's Correspondence with Brutus*, defending at the same time the authenticity of those epistles. Being resolved now to close his studies in profane literature, he in 1745 gave an account in his *Germana quædam Antiquitatis Eruditæ Monumenta*, &c., of the specimens of ancient art which had come into his possession during his residence at Rome; and in 1747 he wrought up into a *Treatise on the Roman Senate* the substance of his letters to Lord Harvey twelve years before, on the constitution of that celebrated institution. Now that his classical studies were completed, he immediately brought forward his *Introductory Discourse*, &c., *to the Free Inquiry into the Miraculous Powers which are supposed to have subsisted in the Christian Church from the earliest ages through several Successive Centuries*,—a work which appeared in 1749, and met with all but universal condemnation from the clergy, on account of its supposed antagonism to the authority of miracles. All that Middleton intended, however, in this vigorous work, was to place Protestant divines in the dilemma of either denying the authority of the fathers altogether, or, by accepting their testimony, to embrace the doctrines of the Romish Church, which he held to be clearly established by the evidence of the fathers. Gibbon, the historian, among others, chose the patristic horn, and became a Roman Catholic. In 1750 Middleton published his last work, *An Examination of the Bishop of London's* [Sherlock] *Discourses on the Use and Intent of Prophecy*, &c., which was not considered equal to some of his previous productions. He died at Hildersham on the 28th of July 1750, in the sixty-seventh year of his age. Shortly before his death he subscribed the Thirty-nine Articles, on occasion of receiving a small living from Sir John Frederick,—an act which some of his brethren, as might have been expected, were inclined to characterize as insincere.

Middleton's miscellaneous works, exclusive of the *Life of Cicero*, were published in 1755 in 5 vols., containing some short pieces not previously published. Among his papers were found some materials for a life of Demosthenes, similar to that of the Roman orator, but he did not survive to complete his design.

MIDDLETON, *Sir Hugh*, was the sixth son of Richard Middleton, Esq., governor of Denbigh Castle in Denbighshire. The date of Sir Hugh's birth and the events of his early life are not known, until his great undertaking of supplying the city of London with water. He had been, however, a goldsmith in the metropolis, and had enriched himself by the successful working of certain copper mines in Wales. Nothing had been done by the citizens of London beyond securing the legal right during Elizabeth's reign of bringing water from any part of Middlesex or Hertfordshire to the metropolis, when, on 28th March 1606, this "citizen and goldsmith" came forward and proposed to bring a supply of water to London at his own cost. Two years afterwards he commenced his work at the Chadwell and Amwell springs, near Ware in Hertfordshire, and after encountering much annoyance and hard labour, the indefatigable and princely goldsmith saw the water in the cistern at Islington on Michaelmas day 1613. But if Middleton had the pleasure of seeing his stupendous undertaking completed, he had also the mortification to find his fortune well-nigh exhausted. He had been aided in the work by King James I.; and in acknowledgment of the generous services of this worthy citizen, his majesty knighted him, and afterwards created him a baronet. Sir Hugh was one of the principal shareholders in connection with the New River Company, but the profits amounted at first to the merest trifle—being little more than L.10 during the first eighteen years; and it is supposed that Middleton at his death left a numerous family not very well provided for.

MIDDLETON, *Thomas*, a distinguished dramatist, who flourished during the reigns of Elizabeth, James I., and Charles I., and respecting whom very little is known. He was chronologer to the city of London in 1620, and is supposed by Malone to have died in 1626. While Middleton does not belong to the first rank of dramatic writers, he was nevertheless highly esteemed by the men of his time, and had the honour of being joint worker, according to the generous fashion of that age, with Jonson, Massinger, Fletcher, and Rowley. His plays, which are very numerous, are often characterized by extravagant incidents, rough rollicking scenes from low life, and bustling, lively plot. His most popular plays, perhaps, are his *A Mad World my Masters*, and the *Roaring Girl;* the latter of which abounds in curious and richly-coloured pictures of London life, interspersed with plenty of slang and coarseness, not unbecoming the heroine, the well-known Moll Cutpurse, who was a real character, and who was brought upon the stage by more than one dramatist of that period. Shakspeare is said to be considerably indebted in the incantations of his *Macbeth* to a play of Middleton's called the *Witch*.

MIDDLETON, *Thomas Fanshaw, D.D.*, the first English Bishop of Calcutta, was born at the village of Redleston in Derbyshire, on the 26th of January 1769, where his father, Rev. Thomas Middleton, was rector. He received his early education at Christ's Hospital, London, and then entered Pembroke Hall, in the university of Cambridge, where he graduated with honours in 1792. Having received ordination, he became a curate at Gainsborough in Lincolnshire, where he for some time edited a periodical publication called the *Country Spectator*. In 1795 he was presented by Dr Pretyman, Archdeacon of Lincoln (to whose sons he had for some time been tutor), to the rectory of Tansor in Northamptonshire; and in 1799 he was made curate of St Peter's, Mancroft. His former patron in 1802 presented him to the rectory of Bytham in Lincolnshire, when he commenced to write *The Doctrine of the Greek Article, applied to the Criticism and Illustration of the New Testament*,—a work which caused considerable controversy, especially among the Unitarians, on its first appearance in 1808. In 1812, after taking his degree of Doctor of Divinity at Cambridge, he received the archdeaconry of Huntingdon, and took up his residence at St Pancras, Middlesex, of which he had been recently appointed vicar.

Calcutta having about this time been made a bishop's see, Dr Middleton was appointed the first bishop on the 8th May 1814. In this position he displayed great diligence and zeal in promoting the cause of Christianity. He founded the Bishop's College at Calcutta for the education of missionaries for Asia in 1820, and instituted a consistory court at Calcutta. He died of fever at this eastern capital on the 8th of July 1822. Some of his sermons, charges, &c., were collected into a volume, and published at London, with a memoir of the author prefixed by Dr H. K. Bonney in 1824.

MIDDLETON, a manufacturing town of England, county of Lancaster, on the Manchester and Leeds Railway, and on the Rochdale Canal, 5 miles N.N.E. from Manchester. In 1775 it was only an inconsiderable village with 300 inhabitants, but it has now become an important seat of the cotton and silk manufactures. It contains several good streets and well-built houses, and has a parish church erected in the sixteenth century. It has also a grammar and other schools, a mechanics' institute, reading-room, and savings-bank. Coal mines are wrought in the vicinity. Pop. (1851) 5740.

MIDDLETON, a market-town of Ireland, province of Munster and county Cork, at the mouth of a small stream flowing into the N.E. branch of Cork harbour, 14 miles E. from Cork. It has a neat parish church, a Roman Catholic chapel, convent, free grammar school, two national schools, a fever hospital, dispensary, market-house, court-house, and bridewell. There are also two large distilleries, breweries, and flour-mills. It is within a mile of Ballinacurra harbour, where large shipments of agricultural produce and flour take place. Pop. (1851) 3676, besides 2334 in workhouse.

MIDDLETOWN, a city and river-port in the United States of North America, Middlesex county, Connecticut, on the right bank of the Connecticut River at the head of its ship navigation, and 24 miles N.E. from New Haven. It is pleasantly situated, partly on an acclivity commanding a fine prospect. The elevated portion contains many elegant mansions surrounded with spacious and highly ornamented ground. The rest of the town consists of broad parallel streets of usually well-built houses. The principal public buildings are the custom-house and court-house, both elegant edifices, and the latter adorned with a fine Grecian portico. The Wesleyan university here is a flourishing institution, having about 120 students. The wharves are commodious, and have 10 feet of water. The shipping of the port amounted on 30th June 1852 to 14,431 tons enrolled and licensed, of which 14,005 were employed in the coasting trade, and the remainder in the cod and mackerel fisheries. Pop. (1850) 4211.

MIDDLEWICH, a market-town of England, county of Chester, at the confluence of the Rivers Dane and Croke, 20 miles E. of Chester. The town, though small, contains many good houses, and has a commodious parish church, three dissenting places of worship, a free grammar school, a newsroom, and library. Salt is largely manufactured here from brine springs in the vicinity. There are also manufactures of silk and cotton stuffs; breweries and brick works. Pop. (1851) 1235.

MIDHURST, a parliamentary borough and market-town of England, county of Sussex, pleasantly situated on a rising ground on the right bank of the Rother, 11 miles N.N.E. of Chichester, and 50 miles S.W. by S. of London. The town is well built and clean; and the principal buildings are the town-hall, which is neat, and the parish church of St Denis, a plain structure in the Gothic style, which, though formerly small, has been recently considerably enlarged. There are also places of worship for Independents and Baptists. Midhurst has a free grammar school, a national school, several almshouses and other charitable establishments, a literary and scientific institution, and a savings-bank. The remains of the castle of the Bohuns, formerly the lords of Midhurst, are to be seen on an eminence near the river; and in the neighbourhood of the town are the ruins of Cowdray House, the seat of the Montagu family, which was built in the time of Henry VIII., and burnt down in 1793. A new house has been built not far from the old, and is now in the possession of the Earl of Egmont. From the time of Edward II. till the passing of the Reform Bill, Midhurst returned two members to Parliament, but the number has now been reduced to one. Midhurst is the seat of a county court; and three annual fairs are held here. The market-day is Thursday. Pop. (1851) of the parliamentary borough, 7021.

MIDNAPOOR, a district of Bengal, in the province of Orissa, containing an area of 4015 square miles, and about half a million of inhabitants. The bulk of the people are Hindus, but there is a greater proportion of Mohammedans than in most other parts of India. Some portion of this extensive district consists of a jungle swarming with noxious animals, and exceedingly unhealthy, although the land is rich and fertile. This district was formally ceded to the East India Company in 1761. It is traversed by numerous rivers, the principal of which are the Soobunreeka and the Kosai. The country produces abundance of grain, sugar, tobacco, cotton, and indigo. On the sea-shore salt is an important object of manufacture. Its principal towns are Midnapore, Jellasore, Piply, and Narraingur. Midnapore, the capital, formerly possessed a fort, which has been converted into a criminal prison. It is 70 miles W. by S. from Calcutta. Long. 87. 23. E., Lat. 22. 25. N.

MIEL, JAN, called by the Italians *Giovanni della Vite*, a Flemish painter, was born in 1599 at Vlaenderen, a village in the neighbourhood of Antwerp. He studied under Gerard Seghers; and after making considerable progress in his art, he went to Rome, and entered the academy of Andrea Sacchi. But in consequence of a disagreement with his master he left the imperial city for a time, and went to Bologna and Parma, where he further improved himself by the study of the works of the Caracci and of Correggio. Returning to Rome, he executed for the pope several historical paintings of great excellence; but his taste, which seems to have been capricious, now rather inclined to the painting of familiar scenes, after the manner of Bamboccio. He was invited to the court of Charles Emmanuel, Duke of Savoy, whose patronage he enjoyed, and by whom he was honoured with the order of St Maurice. Miel died in 1664 at Turin. His pictures represent chiefly carnivals, fairs, beggars, gypsies, and hunting scenes; and are remarkable as spirited and correct representations of nature; but his colours are in many instances too dark and gloomy.

MIERIS, Francis, an artist, was born at Leyden in 1635. His father, who was a goldsmith, was not favourable at first to the wishes of his son to study the art of painting; but owing to the progress made by Francis in painting on glass, he was induced to allow him to enter the school of Gerard Douw. The young artist soon outrivalled all his fellow-students. Mieris is remarkable for the beauty of his colouring and the minuteness and truth of his delineations. The quality of the dresses of his figures can be easily distinguished; and his paintings of silk, satin, and velvet, are highly admired. His subjects are for the most part ordinary domestic scenes. One of these, the picture of a fainting lady and a physician, was sold for 1500 florins. Mieris died in 1681.

Mieris, *Francis*, grandson of the preceding, was born at Leyden in 1689. Although he learned from his father the art of painting, he did not achieve any great success in that department. He is more celebrated as a historian and antiquary, and is the author of several works, of which the most important are:—*Historie der Nederlandsche Vorsten*, the Hague, 1732–35; and *Groot Charterboek der Graven van Holland, Zeeland, en Vriesland*, Leipsic, 1753–56. He died suddenly in 1763, while engaged in writing a history of his native town.

Mieris, *William*, an artist, the son of Francis Mieris the Elder, was born at Leyden in 1662. He imitated the style of his father, but having lost him by death just as he was entering on the study of his art, he was deprived of the advantage he might otherwise have derived from his skill and experience. As a painter, he is not equal to his father in the nice and elaborate accuracy of his works; but for bright and gorgeous colouring, and for the minuteness of his imitation of natural objects, his pictures are much esteemed, and sometimes even placed above those of his father. He has painted many ordinary scenes from nature, and also many historical and poetical pieces. His landscapes are often unnatural, and his costumes are not always appropriate. He died in 1747.

MIGNARD, Nicolas, a French artist, was born at Troyes in Champagne about the year 1605. He was brought to Paris by Mazarin, who was his constant patron; and Louis XIV. employed him to execute several paintings in the Tuileries. He was most successful in historical and poetical subjects; but he also painted many portraits of the lords and ladies of the French court, which are much admired. He died in 1668.

Mignard, *Pierre*, an eminent French artist, brother of the preceding, was born at Troyes in 1610. At the age of eleven he was placed in the school of Jean Boucher at Bourges; and he afterwards studied under Vouet. Such was his genius, and so rapid was his progress in his art, that his works could hardly be distinguished from those of his master; and at the age of fifteen he was commissioned by the Marshal of Vitry to execute some paintings in his castle. In 1636 he went to Rome, where he remained for twenty-two years, engaged in the study of the works of the best Italian painters, and forming his style so much upon the model of the Roman school that he acquired the surname of *Il Romano*. He painted many historical pieces and portraits; among the latter, in which he displayed his genius and skill in a remarkable manner, were those of the Popes Urban VIII. and Alexander VII. In 1658 he was invited to the court of Louis XIV. He immediately set out on his journey thither; and on his way through the duchies of Tuscany, Modena, and Parma, he executed portraits of the reigning princes of these states. At Paris Mignard was made head of the academy of St Luke; and after the death of Le Brun, became chief painter to the king. He painted Louis XIV. no less than ten times. The following anecdote is related of him as he was taking the tenth portrait of that monarch:—The king, seeing the painter looking at him with attention, said, "Mignard, you think I look older?" "Sire," answered the painter, "it is true that I see some more victories on the forehead of your majesty." Among the principal works of Mignard was the fresco-painting in the dome of the Val-de-Grâce, one of the greatest works of that sort of which his country can boast. It was celebrated in verse by Molière; with whom, as well as with Boileau and Racine, Mignard was very intimate. The paintings of this artist are certainly inferior to those of the great masters whom he took as his models; but they are distinguished for grace and beauty, and he was so extremely successful in his imitations of other painters, as to deceive even the best judges. He died in 1695.

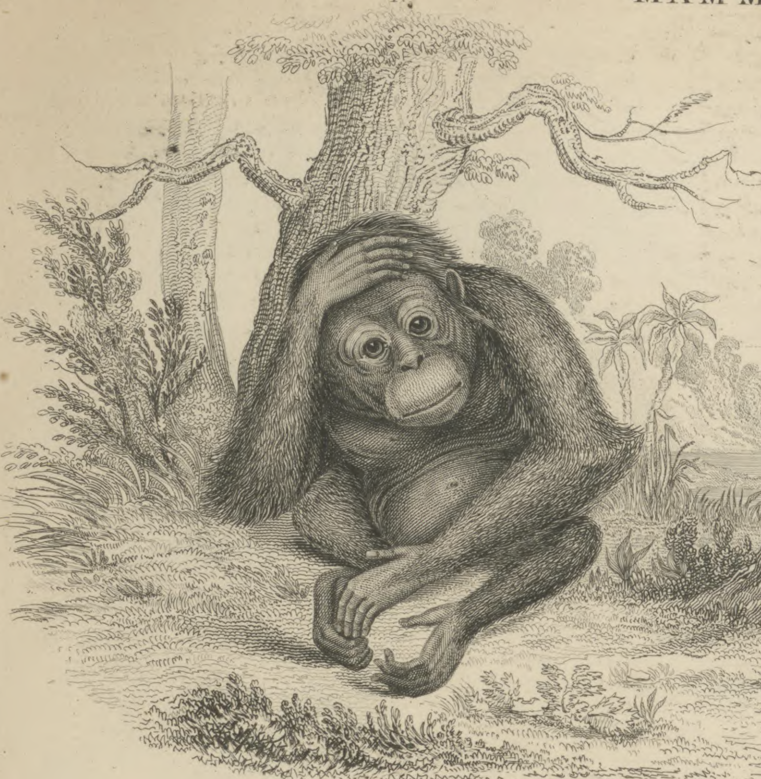
MIGNON, Minion, or Minjon, Abraham, a painter, was born at Frankfort-on-the-Maine in 1640, and studied at Utrecht under Jan David de Heem. Having a natural taste for art, and also great skill and aptitude in painting, he added to these advantages the most unwearied diligence in the imitation and study of nature, and thus soon rose to great eminence as a painter. Mignon is remarkable for the accuracy of his representations and the beauty of his colouring, and his works are in general very highly prized. His paintings, which are rare, represent chiefly flowers, fruit, insects, birds, fish, &c. He died in 1679.

MIHIEL, St, a town of France, department of Meuse, and arrondissement of Commercy, on the right bank of the River Meuse, 9 miles N.N.W. of Commercy. It is a neat and well laid-out town, and has several remarkable churches, in one of which is a fine bas-relief of the "Entombment of Christ." St Mihiel has also a court of assize, communal college, public library; and manufactures of cloth, yarn, and leather. Pop. 5274.

END OF VOLUME FOURTEENTH.

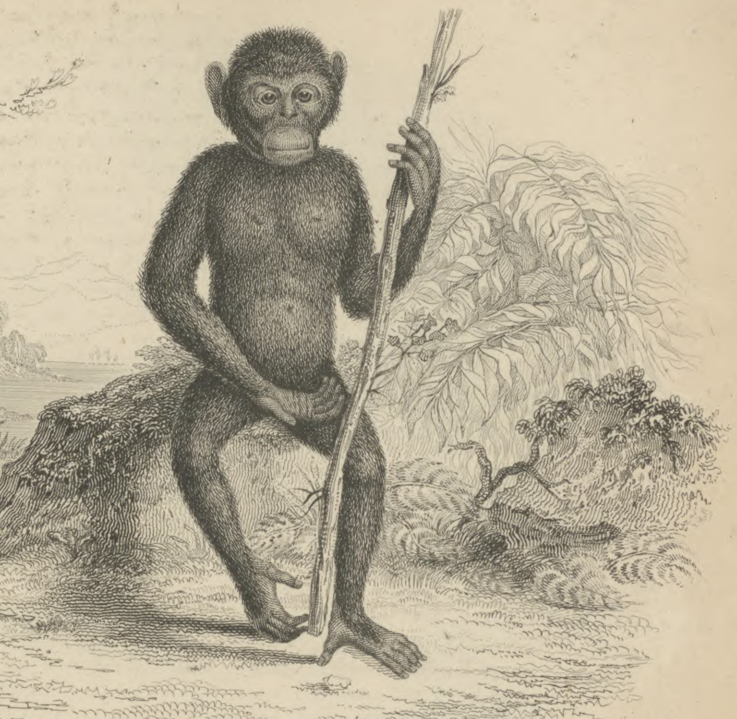
MAMMALIA.

1.



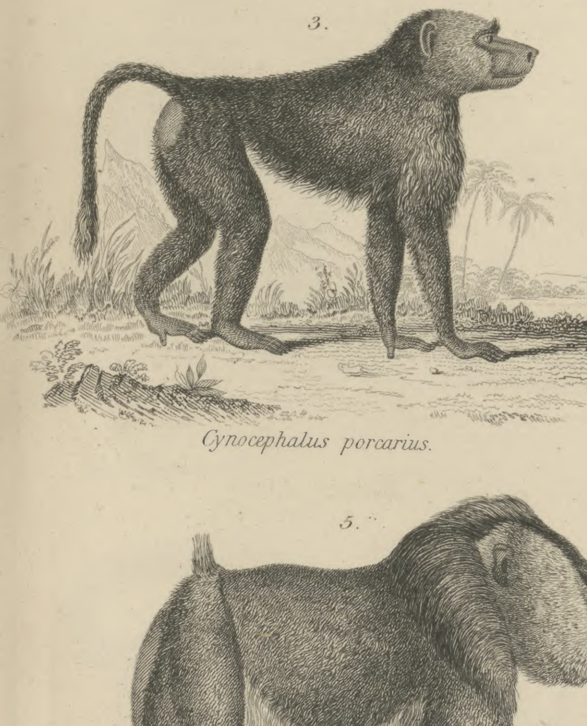
Pithecus satyrus.

2.



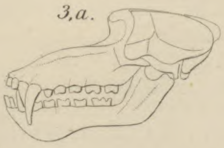
Troglodytes niger.

3.

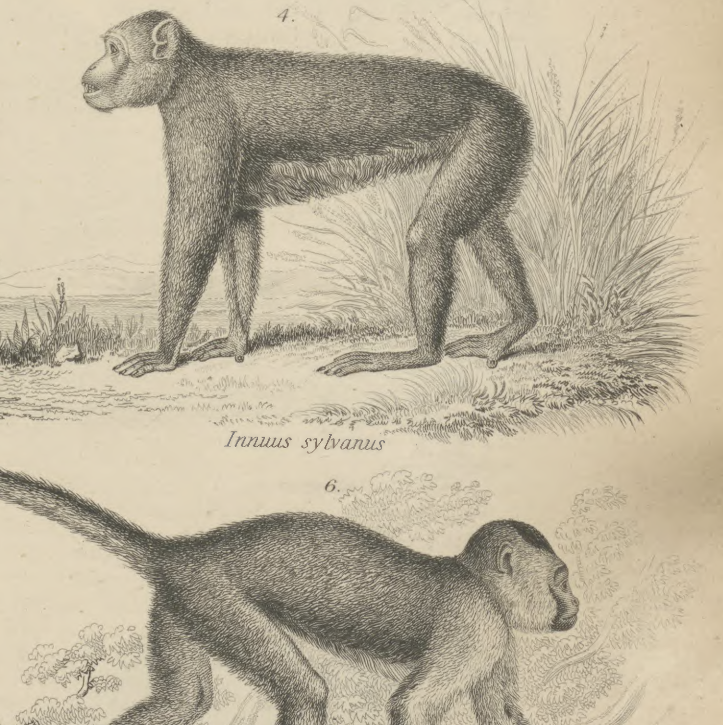


Cynocephalus porcarius.

3,a.

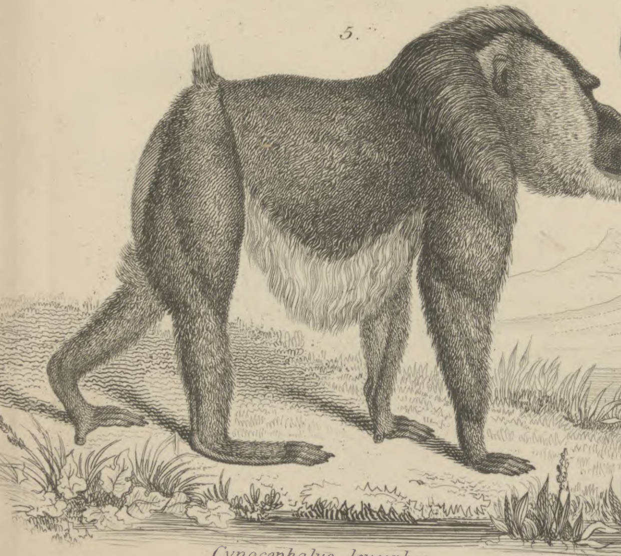


4.



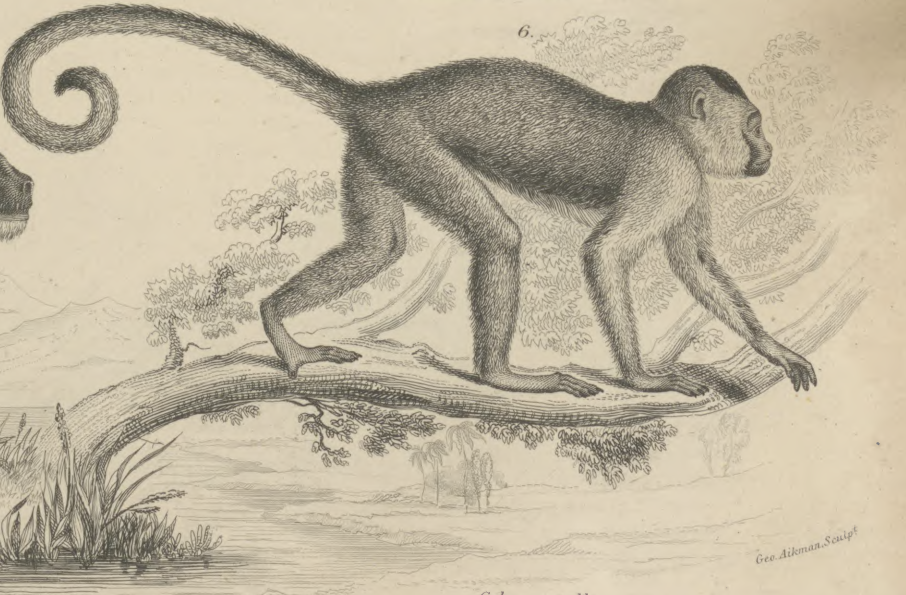
Innuus sylvanus

5.



Cynocephalus leucophæus.

6.

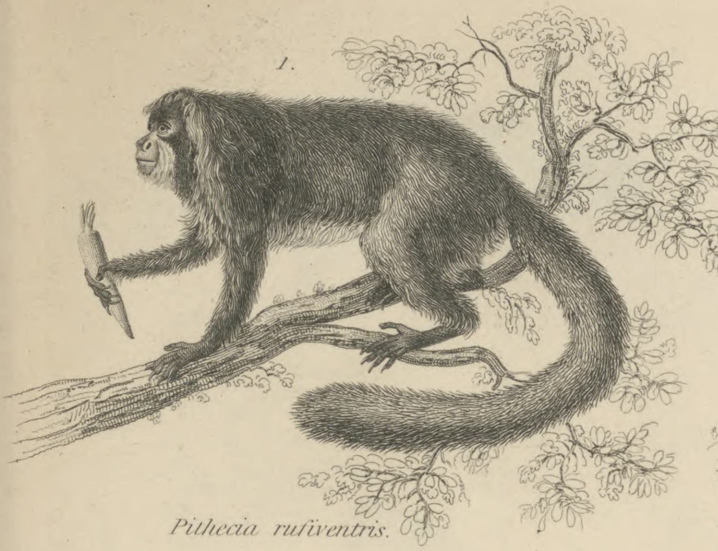


Cebus apella.

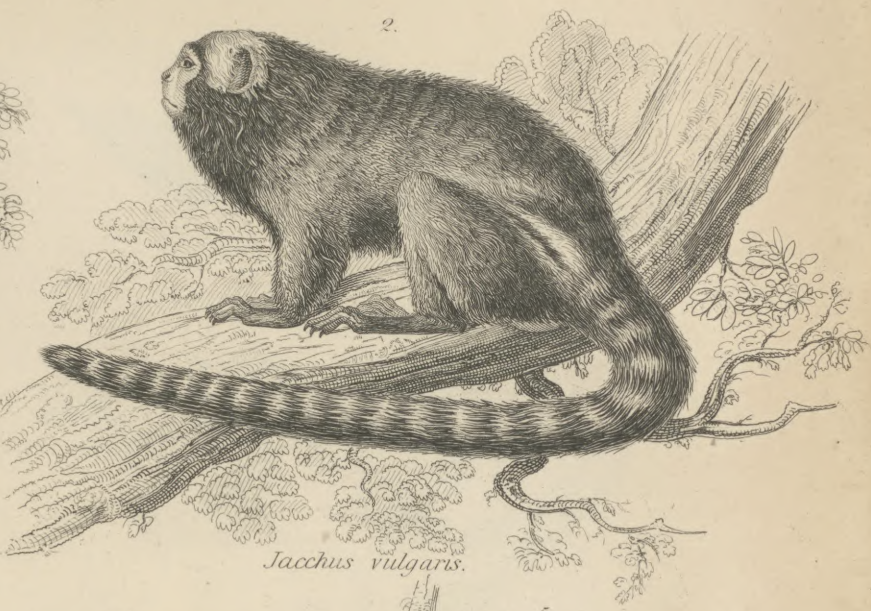
Geo Aikman, Sculpt

Published by A & C. Black. Edinburgh.

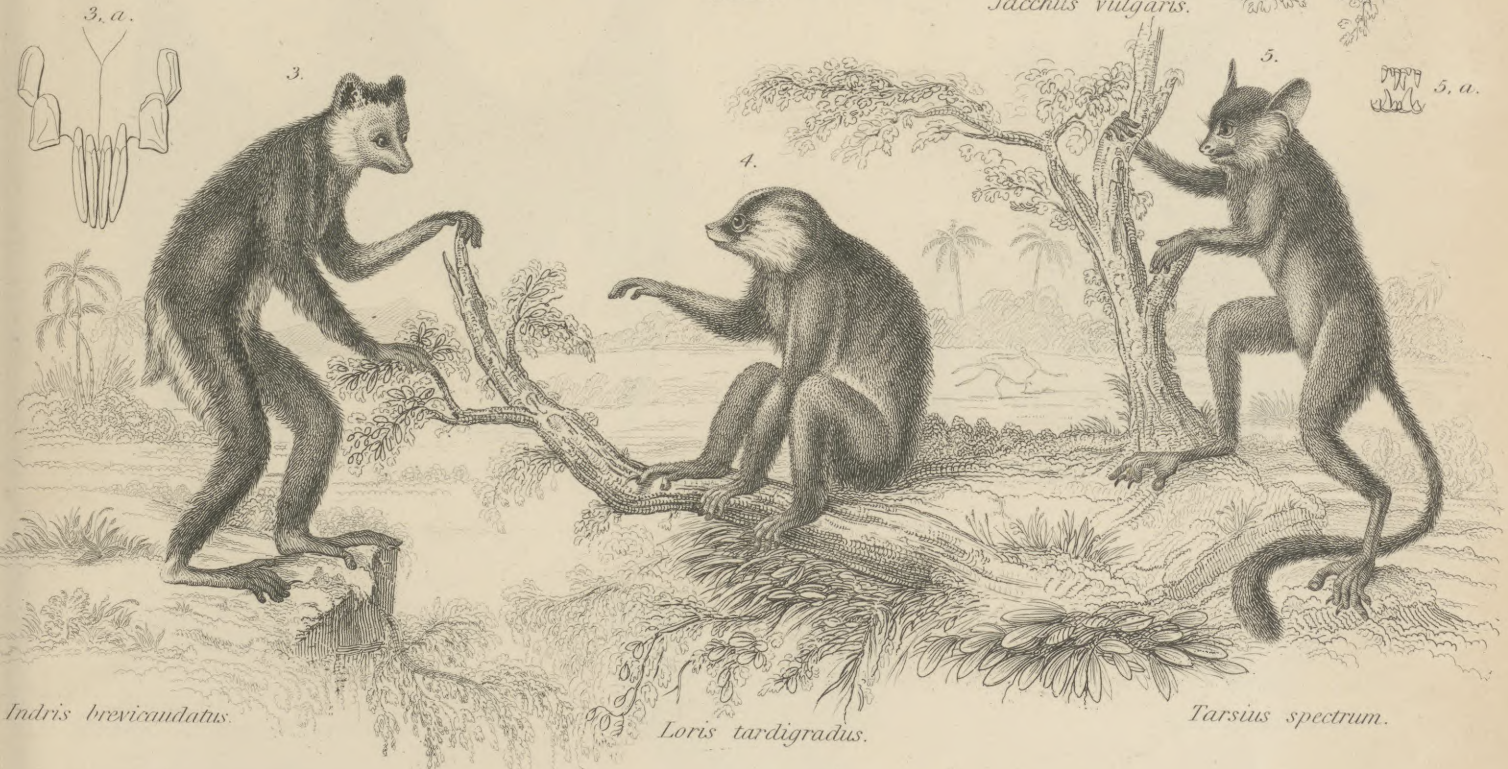
MAMMALIA.



Pithecia rufiventris.



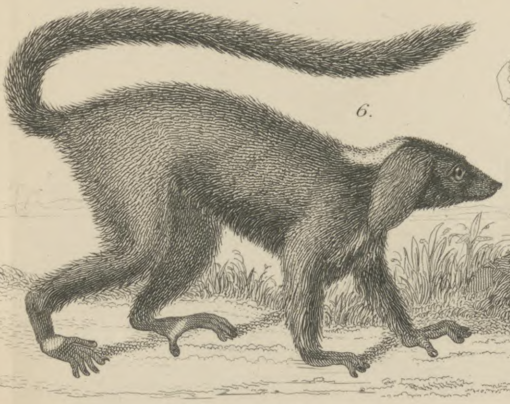
Jacchus vulgaris.

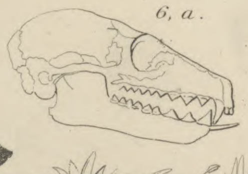


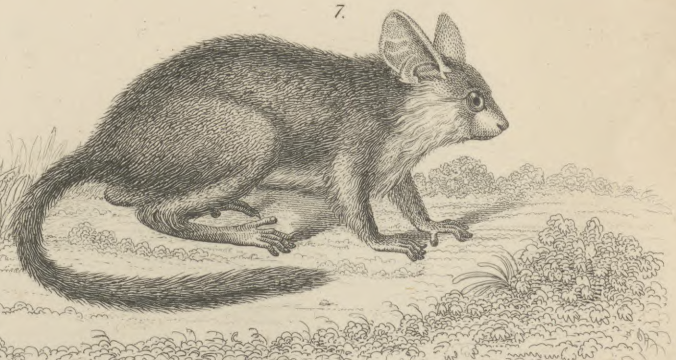
Indris brevicaudatus.

Loris tardigradus.

Tarsius spectrum.







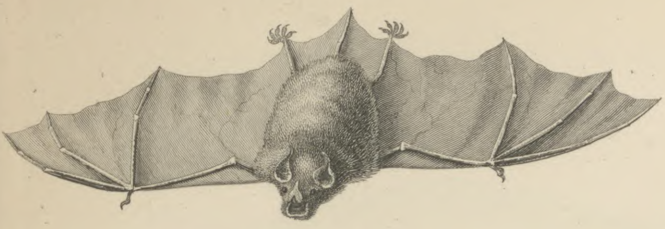
Lemur ruber.

Galago Senegalensis.

Geo. Aikman, Sculpt.

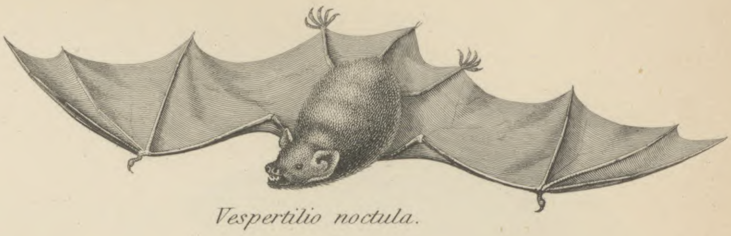
Published by A. & C. Black. Edinburgh.

1.



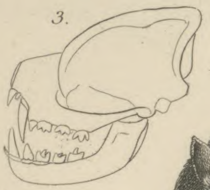
Rhinolophus ferrum-equinum.

2.



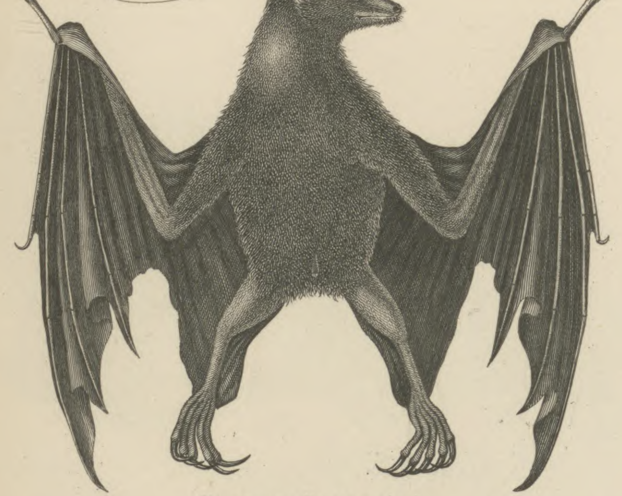
Vespertilio noctula.

3.



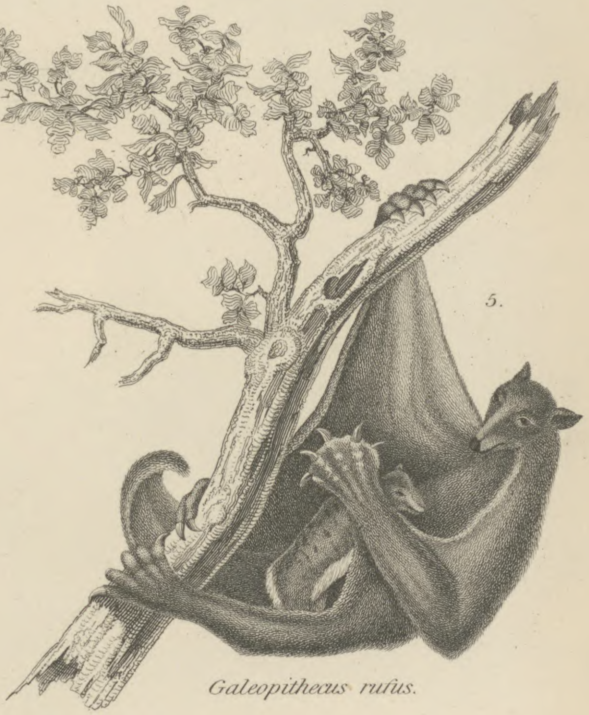
Cranium of Noctilio Leporinus.

4.



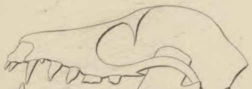
Pteropus Dussumieri.

5.



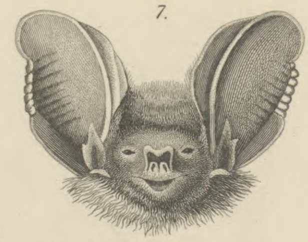
Galeopithecus rufus.

6.



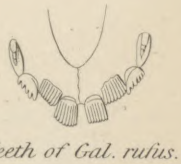
Cranium of Pteropus Keraudrenius.

7.



Plecotus Timoriensis.

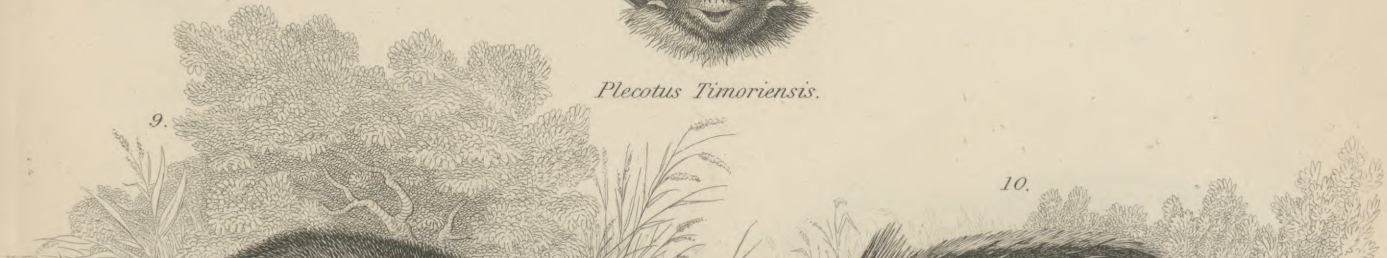
8.



Teeth of Gal. rufus.

9.

10.



Erinaceus Europæus.

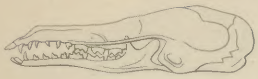
Centenes semispinosus.

Geo. Aikman Sculpt.

Published by A. & C. Black Edinburgh.

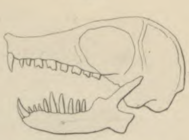
MAMMALIA.

1, a.

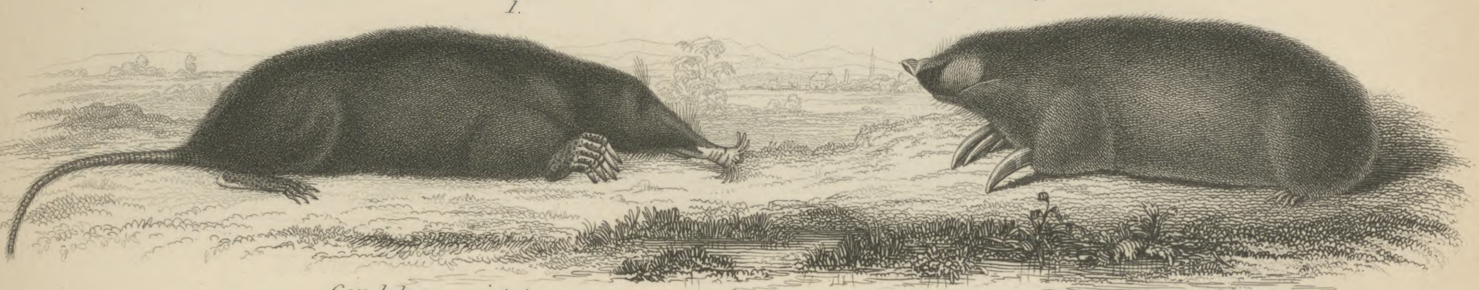


Cranium of 1.

2, a.

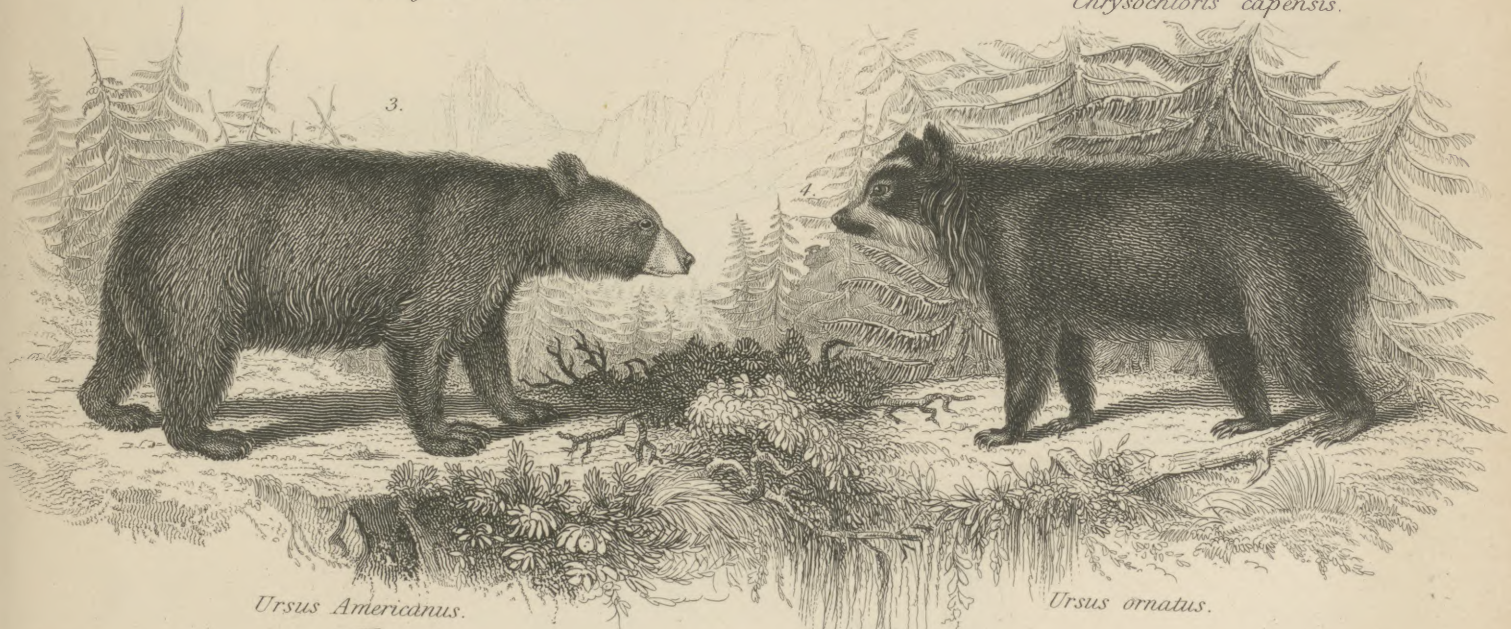


Cranium of 2.



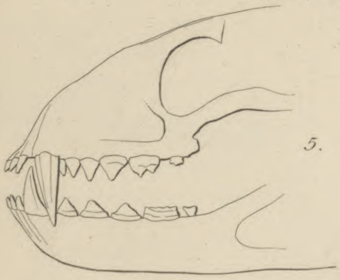
Condylura cristata.

Chrysochloris capensis.



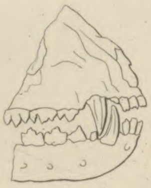
Ursus Americanus.

Ursus ornatus.



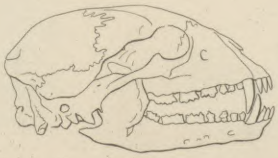
Teeth of Ictides albifrons.

6, a.

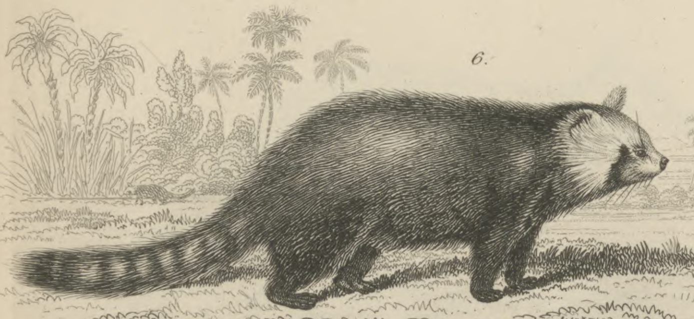


Teeth of 6.

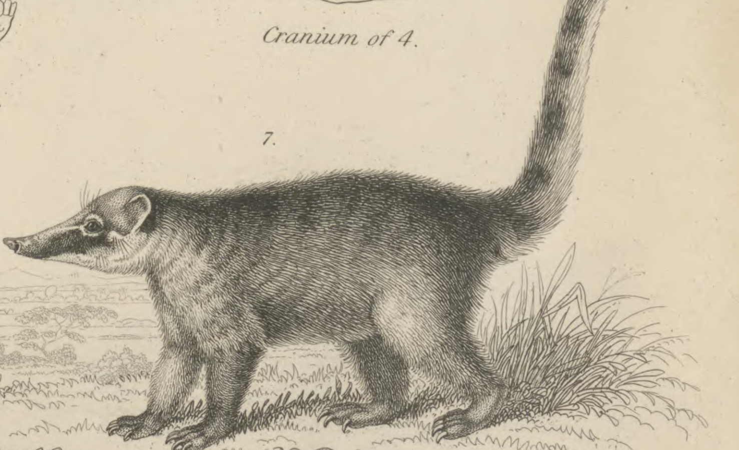
4, a.



Cranium of 4.



Ailurus refulgens.

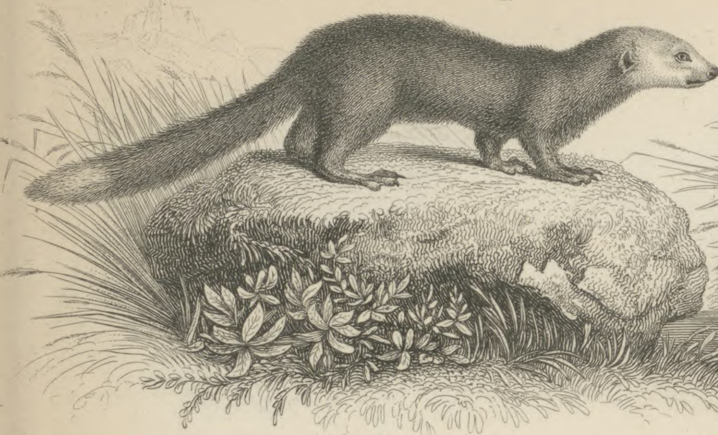


Nasua rufa.

Geo. Aikman, Sculp^t

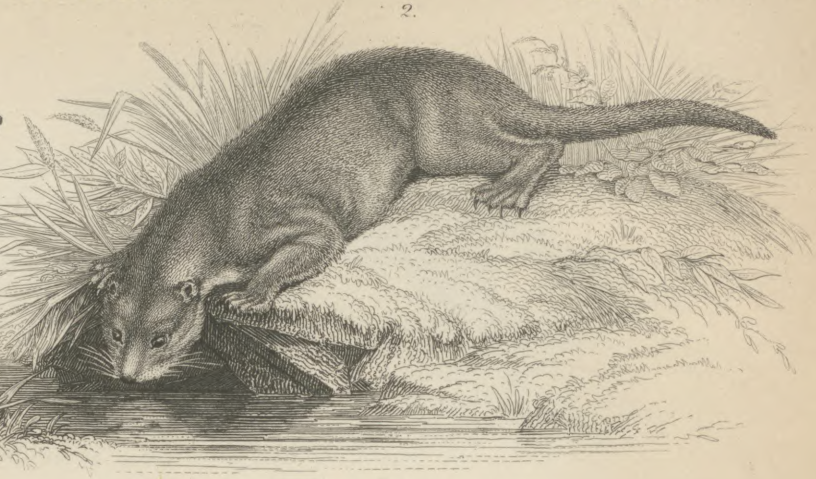
Published by A. & C. Black. Edinburgh.

1.



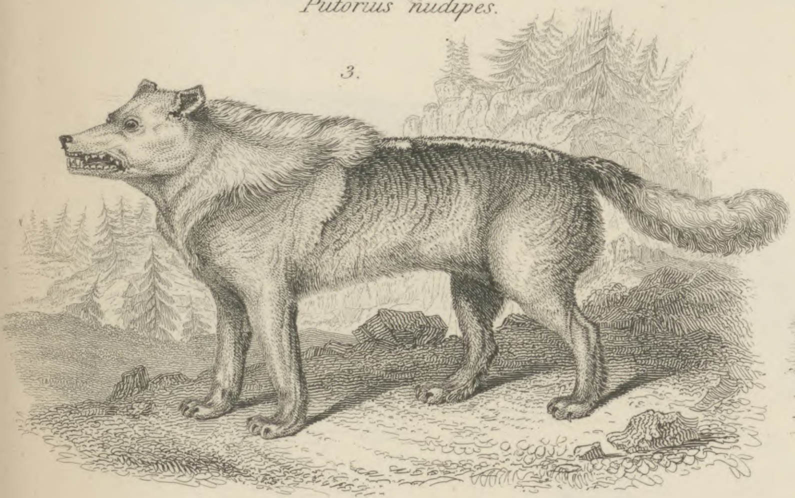
Putorius nudipes.

2.



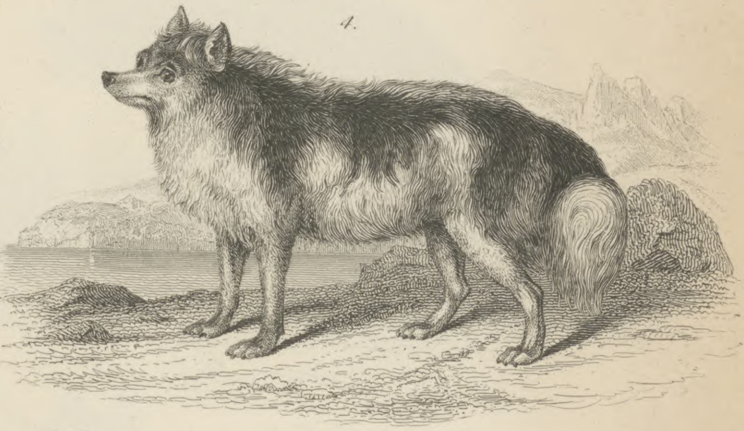
Lutra vulgaris.

3.



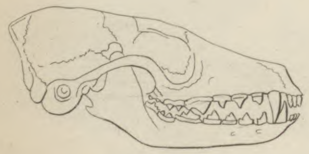
Canis lupus, occidentalis, var. griseus.

4.



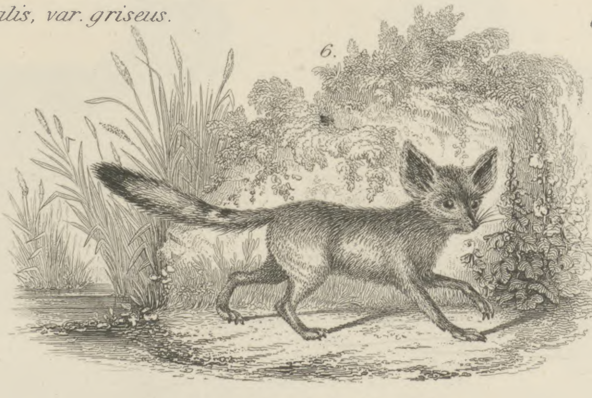
Canis familiaris, var. lagopus.

5.



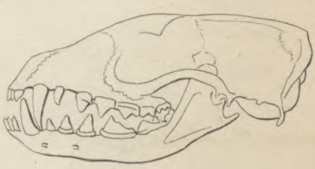
Cranium of Canis vulpes.

6.



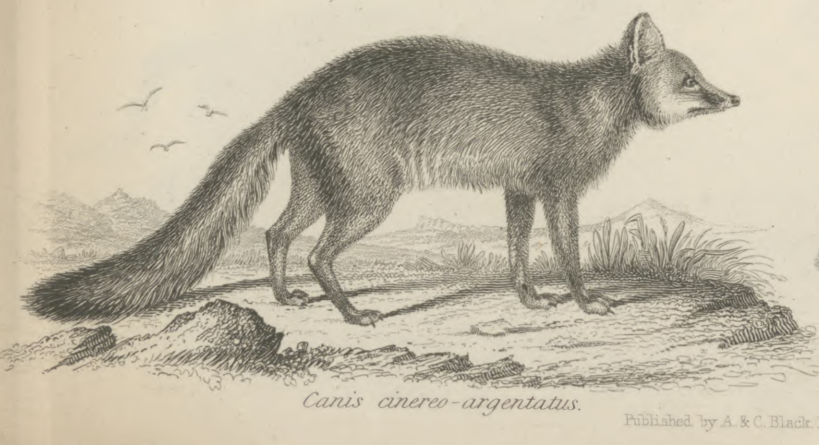
Megalotis Brucei.

8. a.



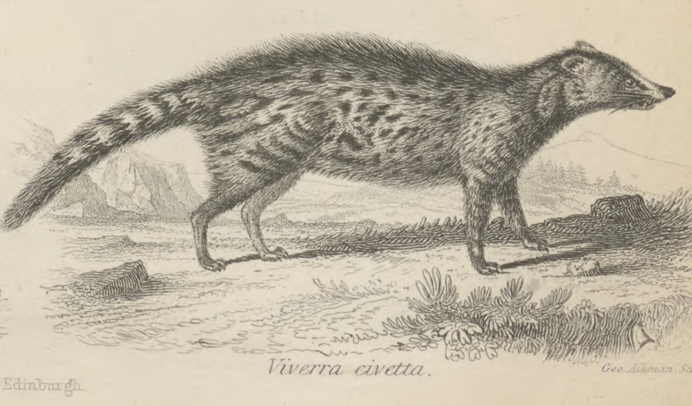
Cranium of 8.

7.



Canis cinereo-argentatus.

8.



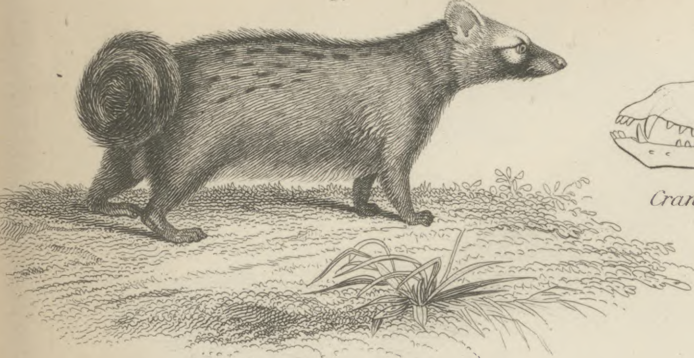
Viverra civetta.

Published by A. & C. Black, Edinburgh.

Geo. Aikman Sculpt.

MAMMALIA.

1.

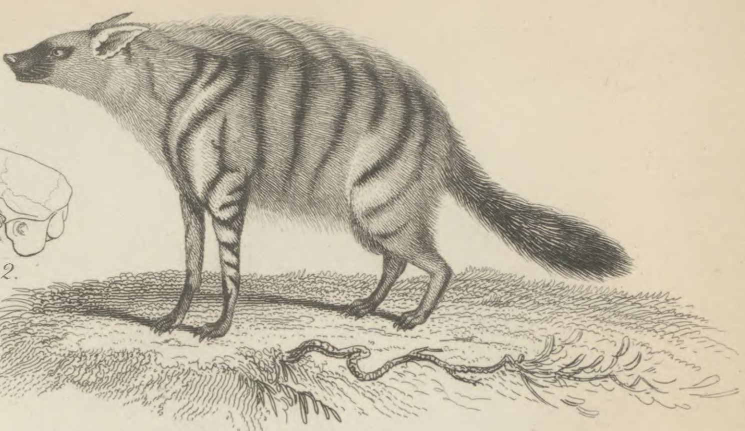


Paradoxurus typus.

2.a.

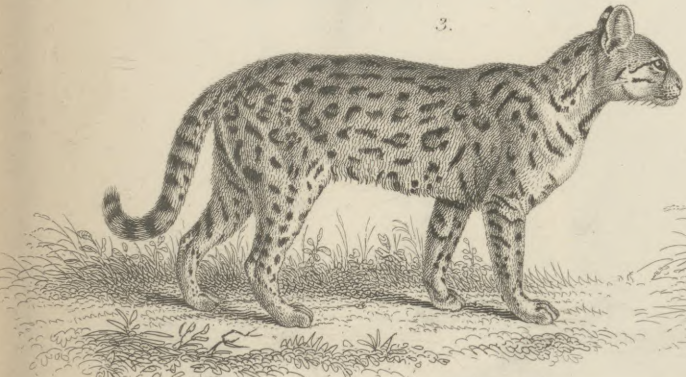
Cranium of 2.

2.



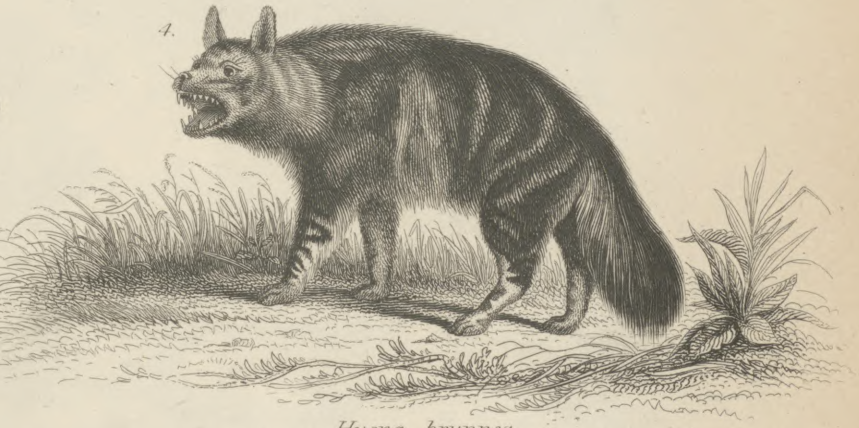
Proteles Lalandii.

3.



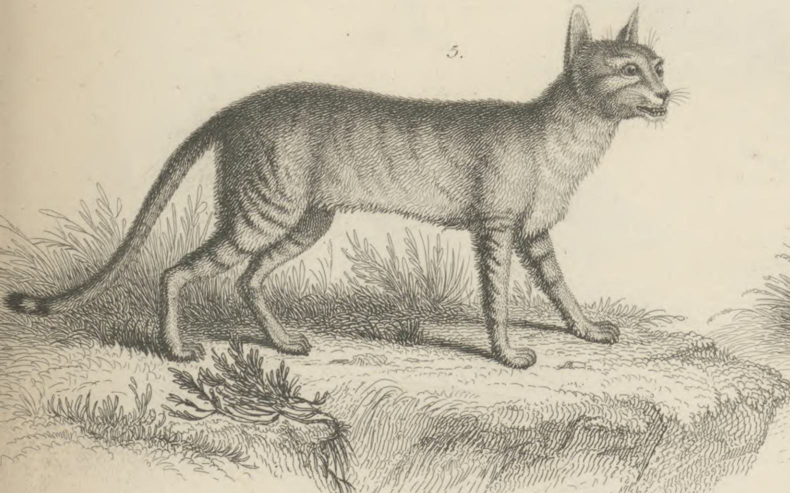
Felis mitis.

4.



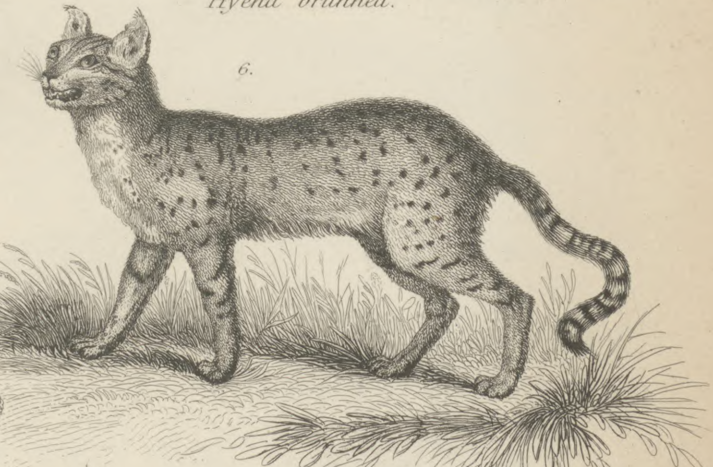
Hyena brunnea.

5.



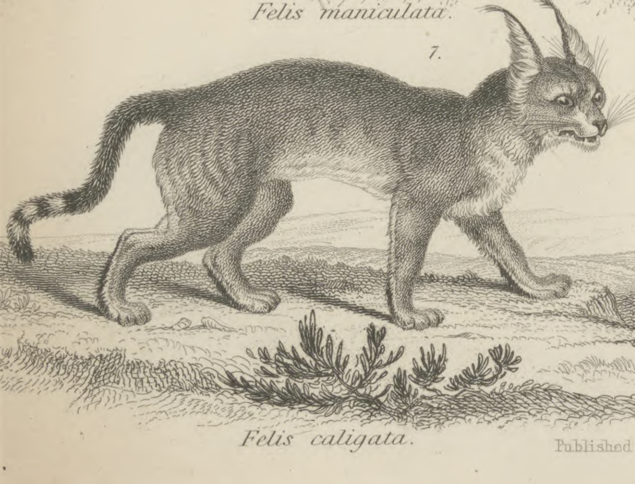
Felis maniculata.

6.



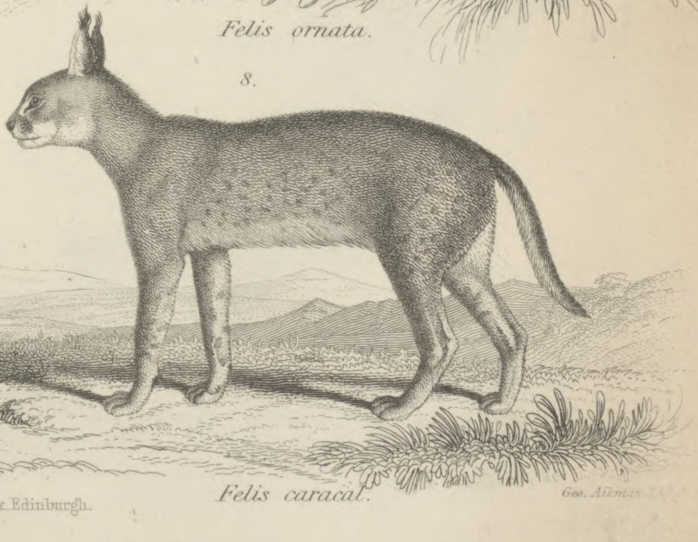
Felis ornata.

7.



Felis caligata.

8.



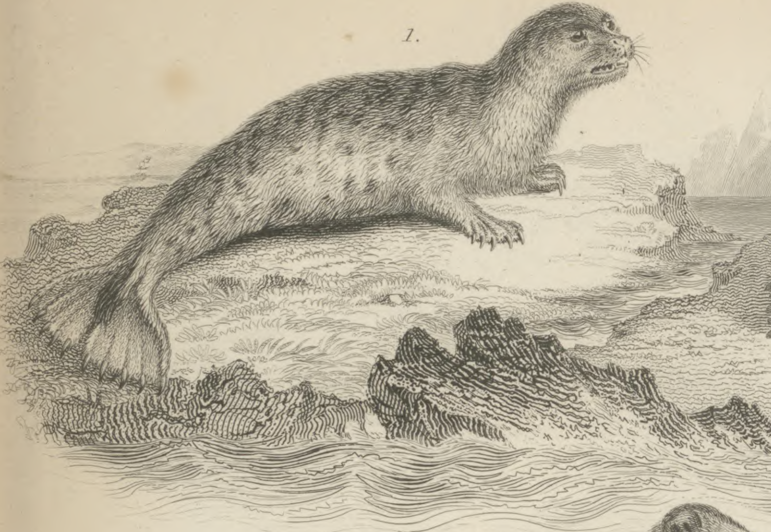
Felis caracal.

Published by A. & C. Black Edinburgh.

Geo. Aikman

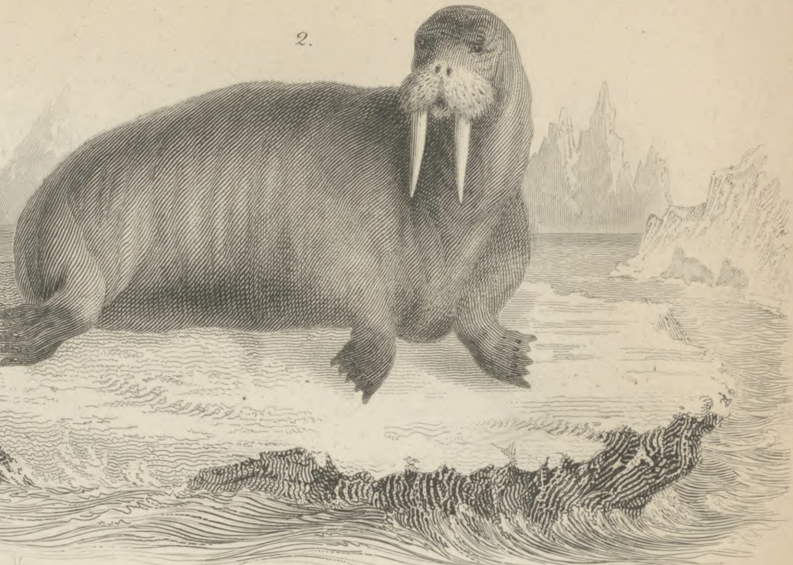
MAMMALIA.

1.



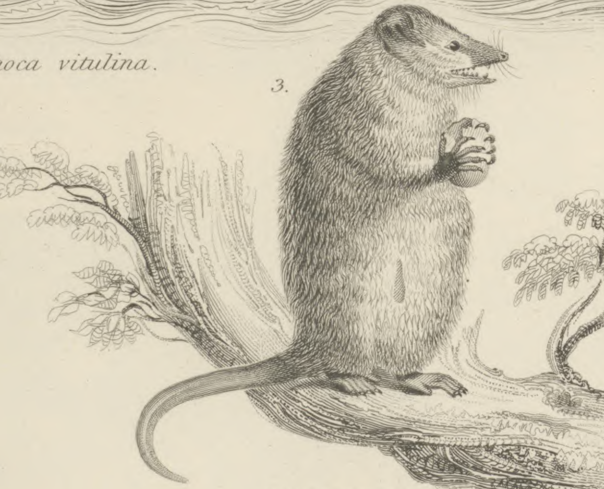
Phoca vitulina.

2.

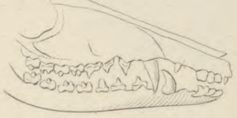


Trichecus rosmarus.

3.

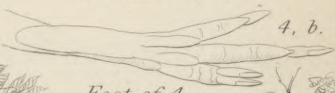


Didelphis virginiana.



4, a.

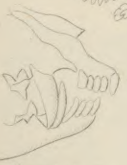
Cranium of 4.



4, b.

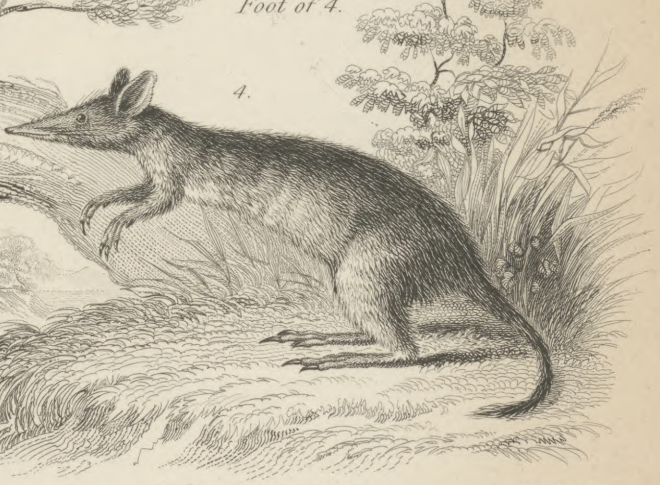
Foot of 4.

5, a.



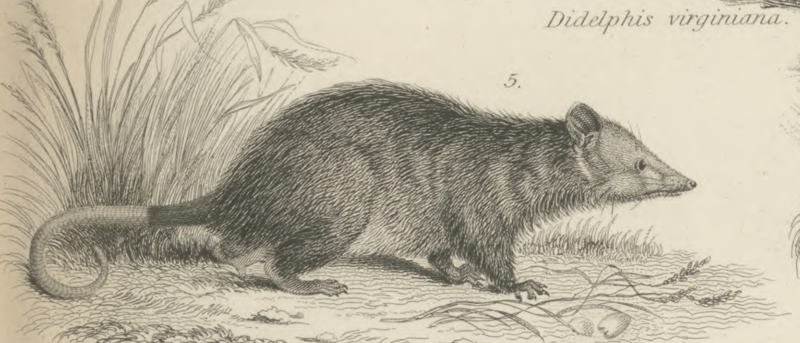
Teeth of 5.

4.



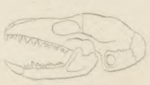
Perameles nasutus.

5.

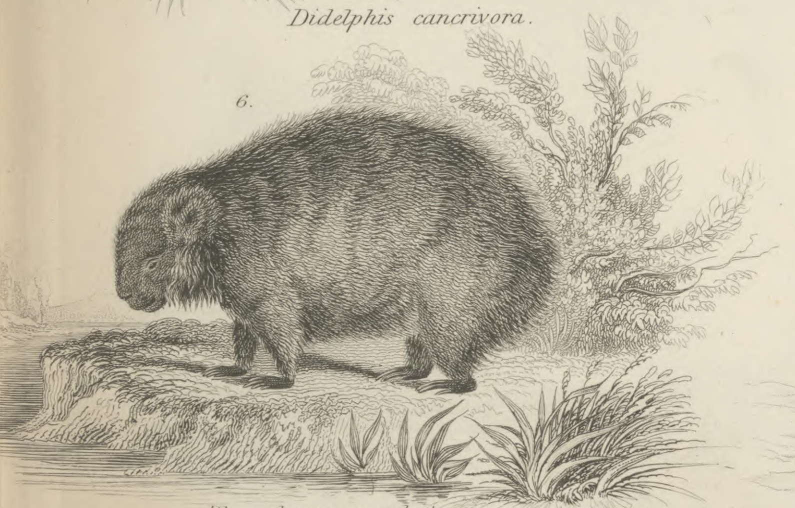


Didelphis cancrivora.

7, a.

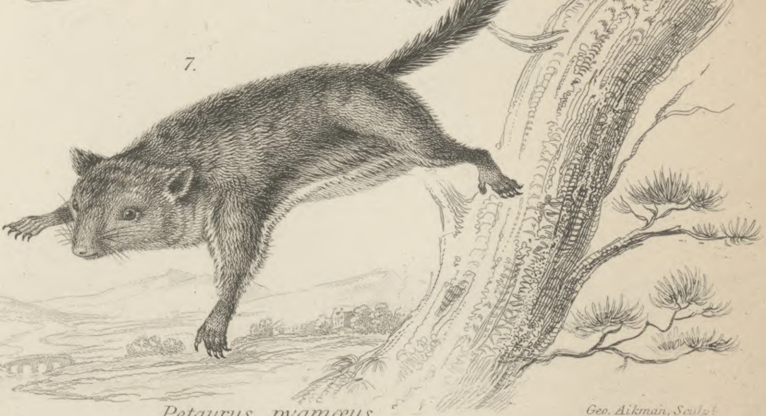


6.



Phascolomys wombat.

7.



Petaurus pygmæus.

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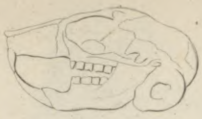
Geo. Aikman, Sculpt.

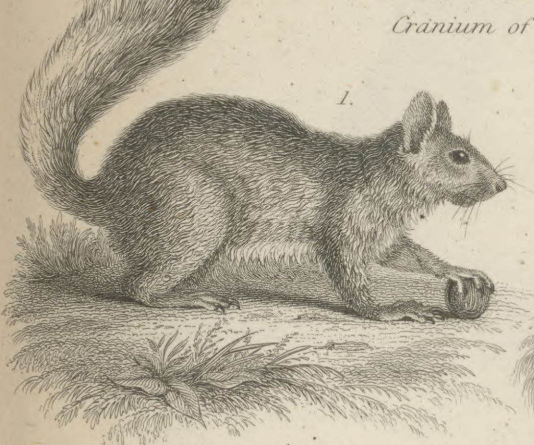
MAMMALIA.

2.



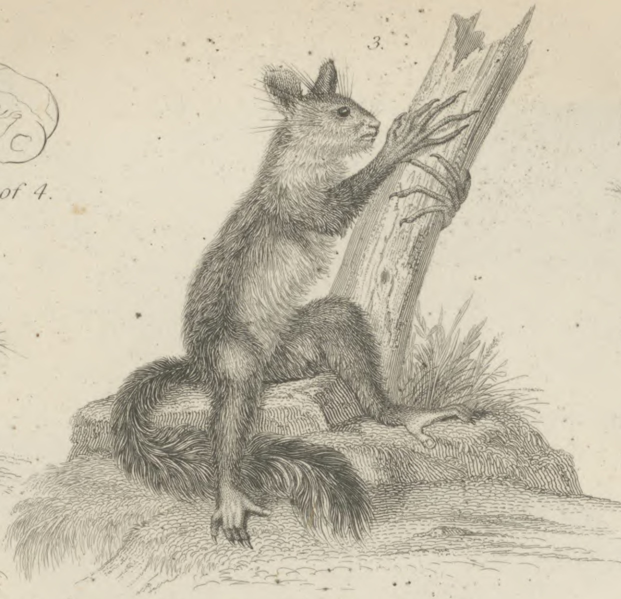
Cranium of 4.

1.



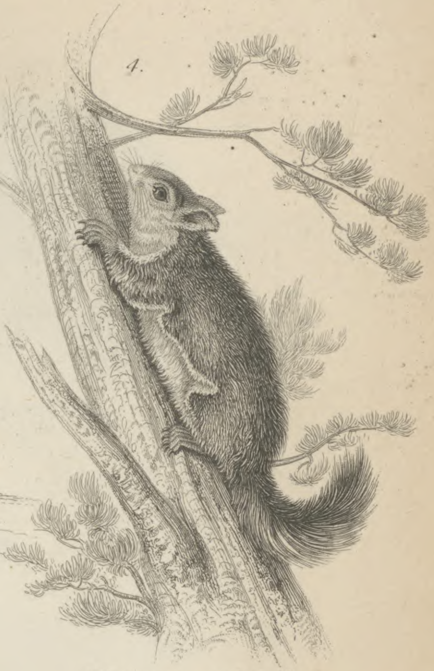
Sciurus cinereus.

3.



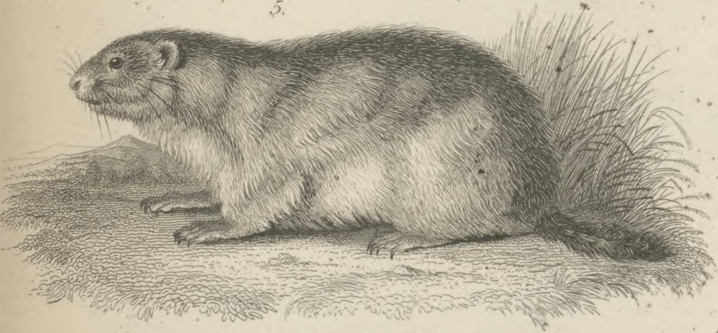
Cheiromys Madagascariensis.

4.



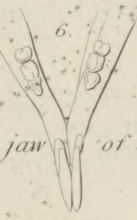
Pteromys volucella.

5.



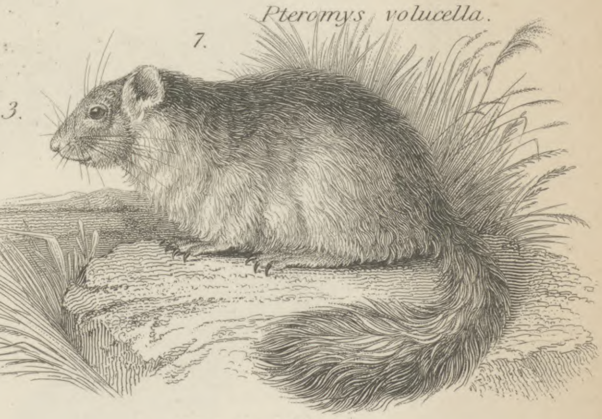
Arctomys empetra.

6.



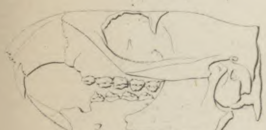
Lower jaw of 3.

7.



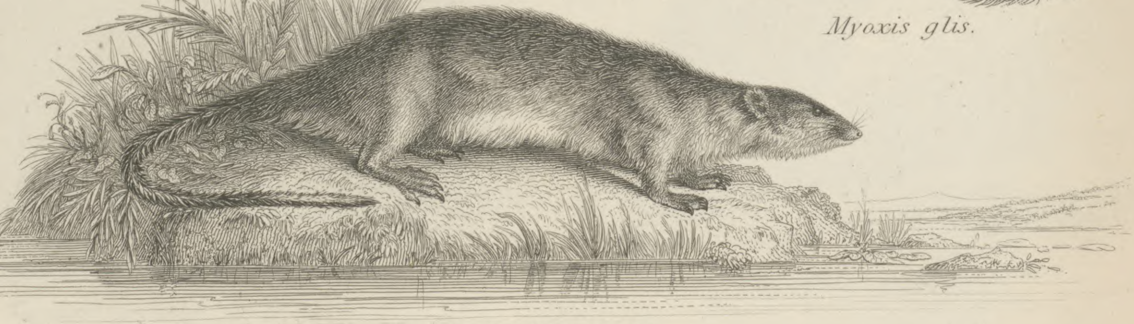
Myoxis glis.

8.



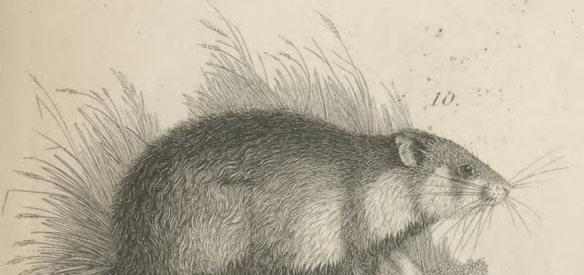
Cranium of 5.

9.



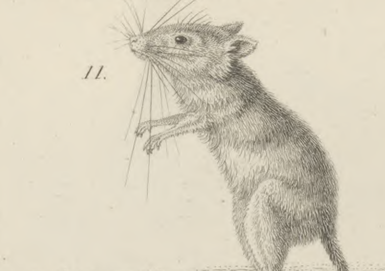
Hydromys chrysogaster.

10.



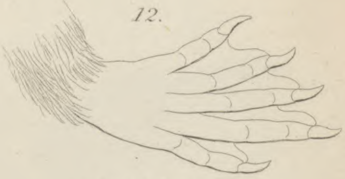
Cricetus vulgaris.

11.



Dipus hirsipes.

12.



Hind foot of 9.

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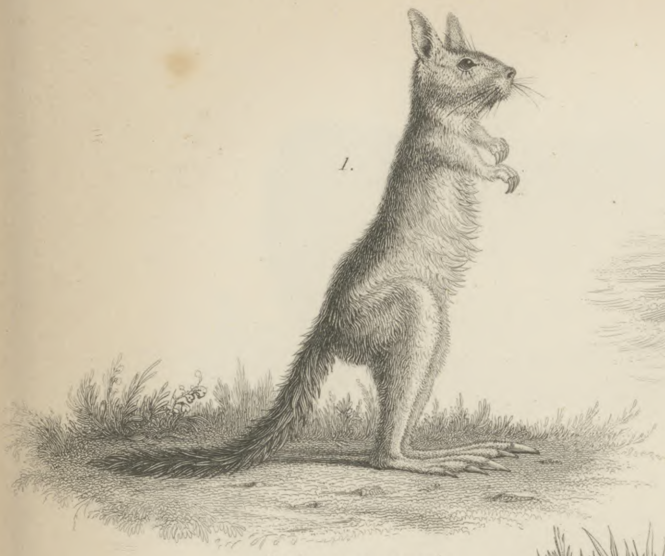
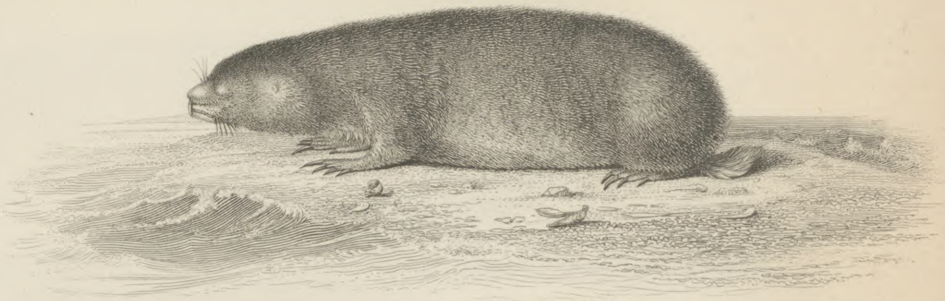
VOL. XIV.

MAMMALIA.

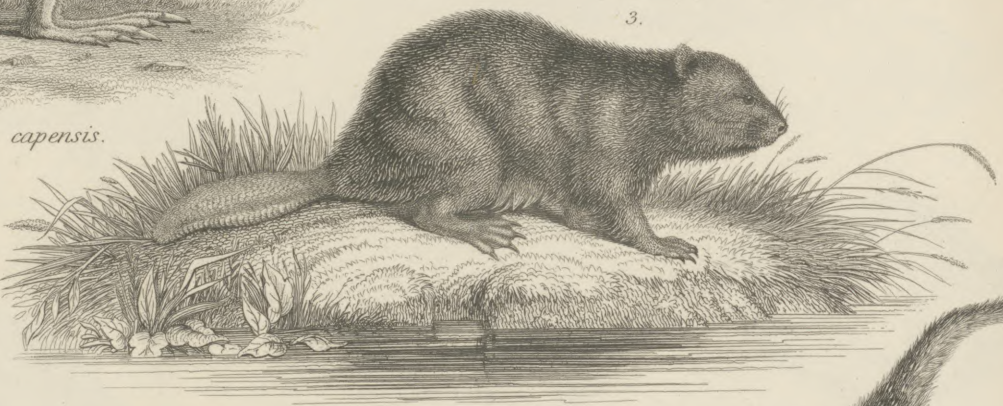
PLATE IX.


1.

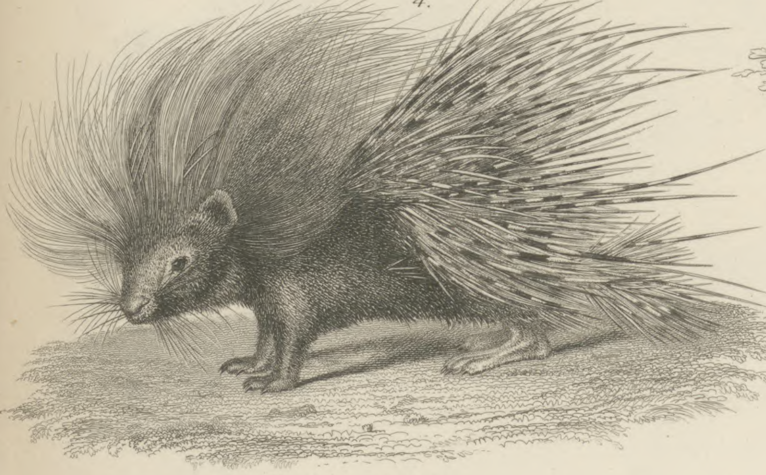
Pedetes capensis.


2.

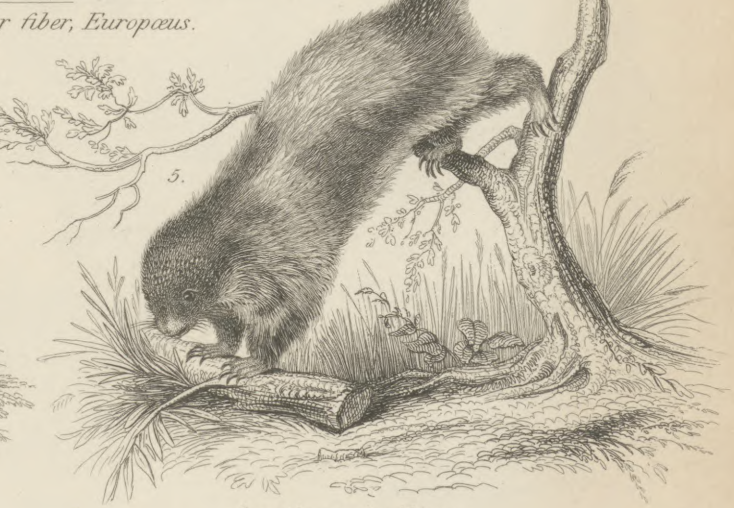
Bathiergus maritimus.


3.

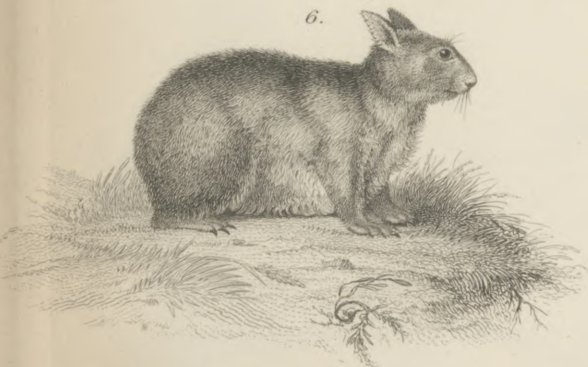
Castor fiber, Europœus.


4.

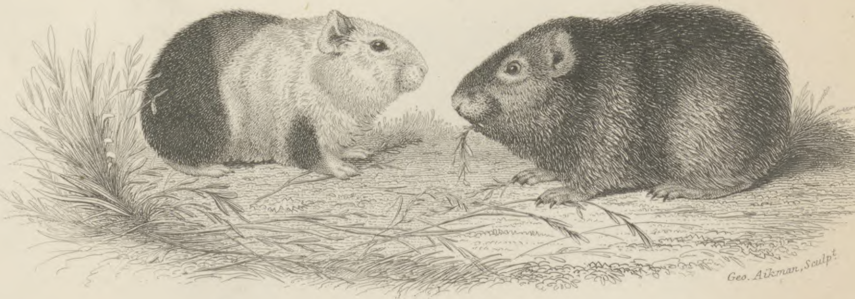
Hystrix cristata.


5.

Synetheres insidiosa.


6.

Lagomys alpinus.


7.

a. b.

Cavia cobaya.

a, domestica. b, Aperea.

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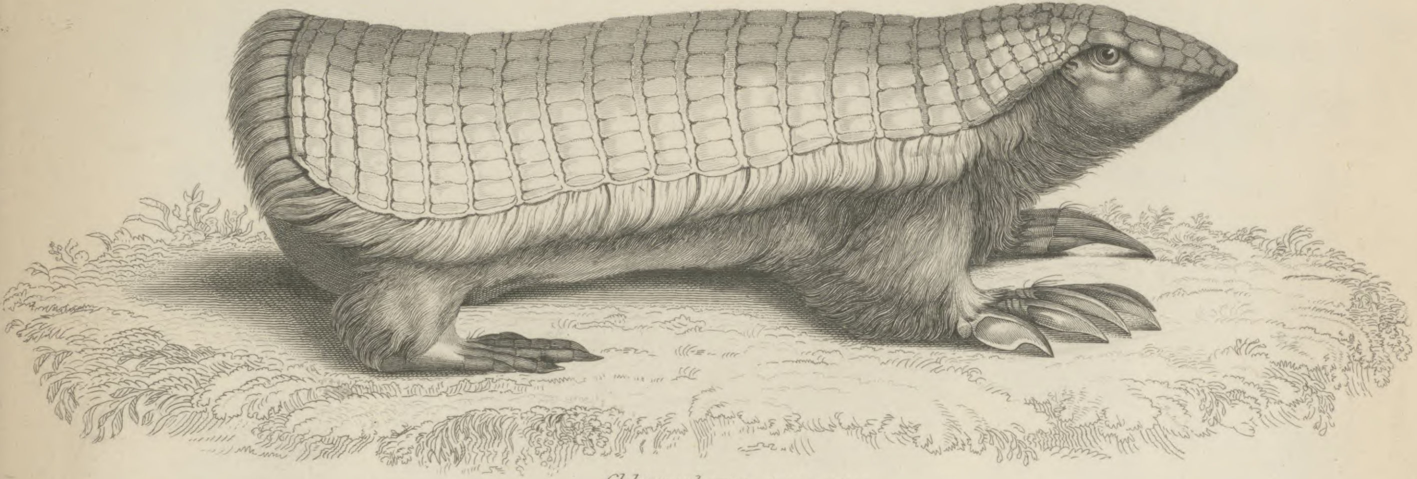
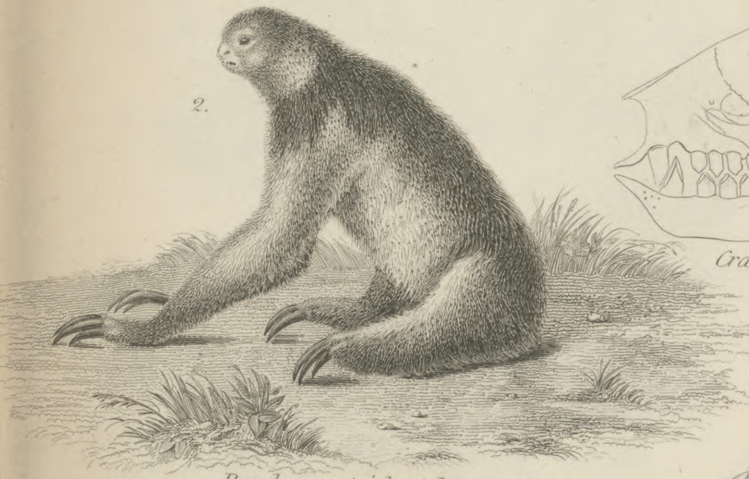
1.



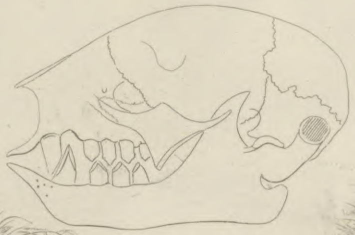
Chlamyphorus truncatus.

2.



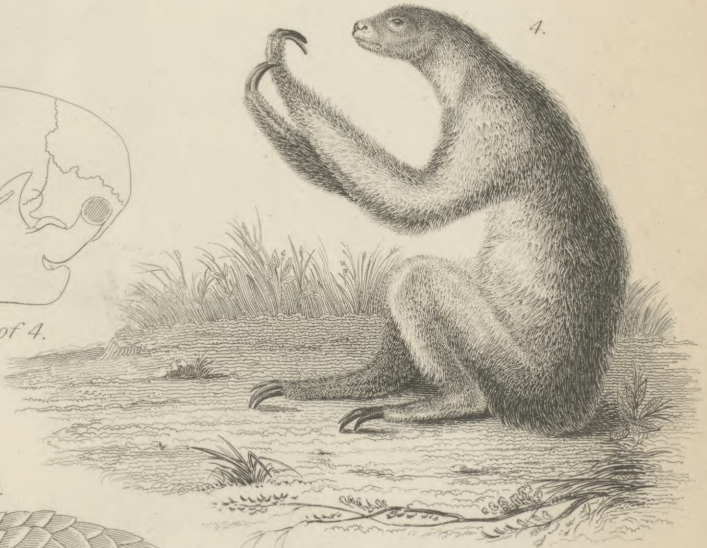
Bradypus tridactylus.

3.



Cranium of 4.

4.

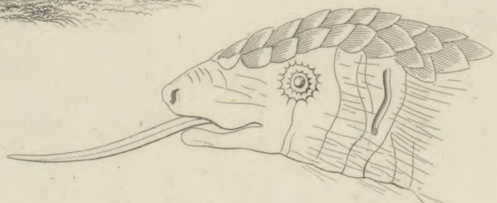


Bradypus didactylus.

5.

Cranium of 8.

6.

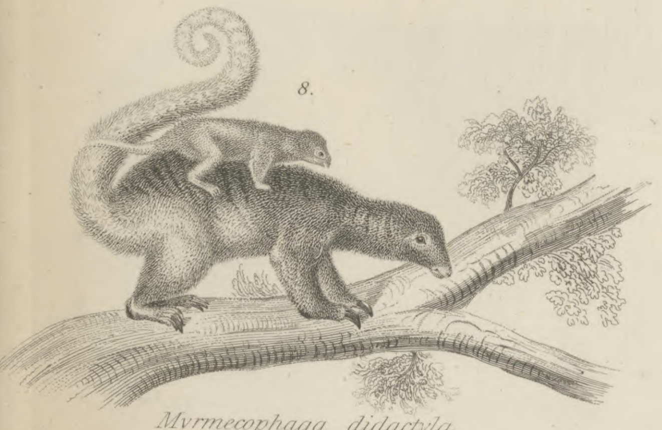


Manis tetradactyla.

7.

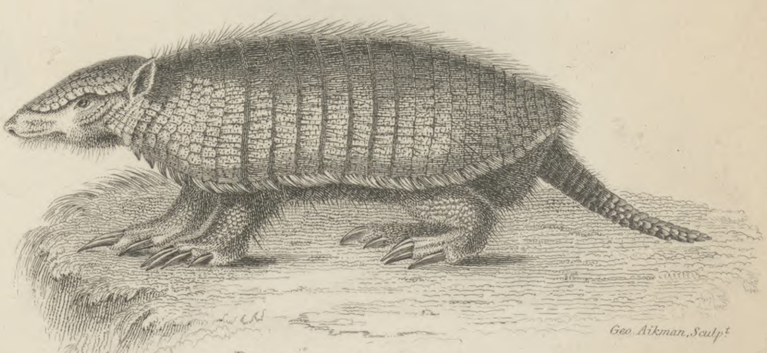
Cranium of 6.

8.



Myrmecophaga didactyla.

9.



Dasypus sexcinctus.

Geo. Aikman, Sculp.t

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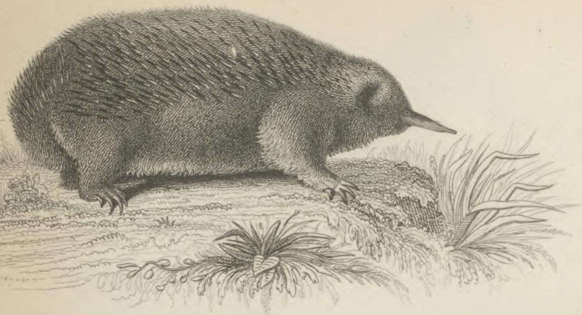
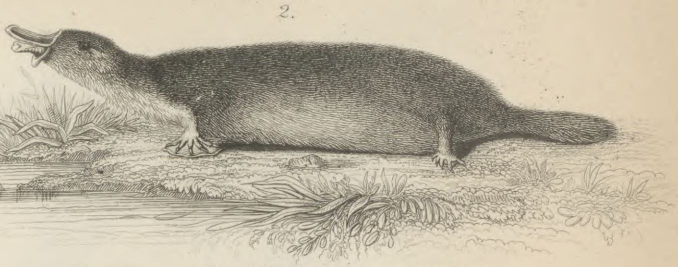
MAMMALIA.

1.



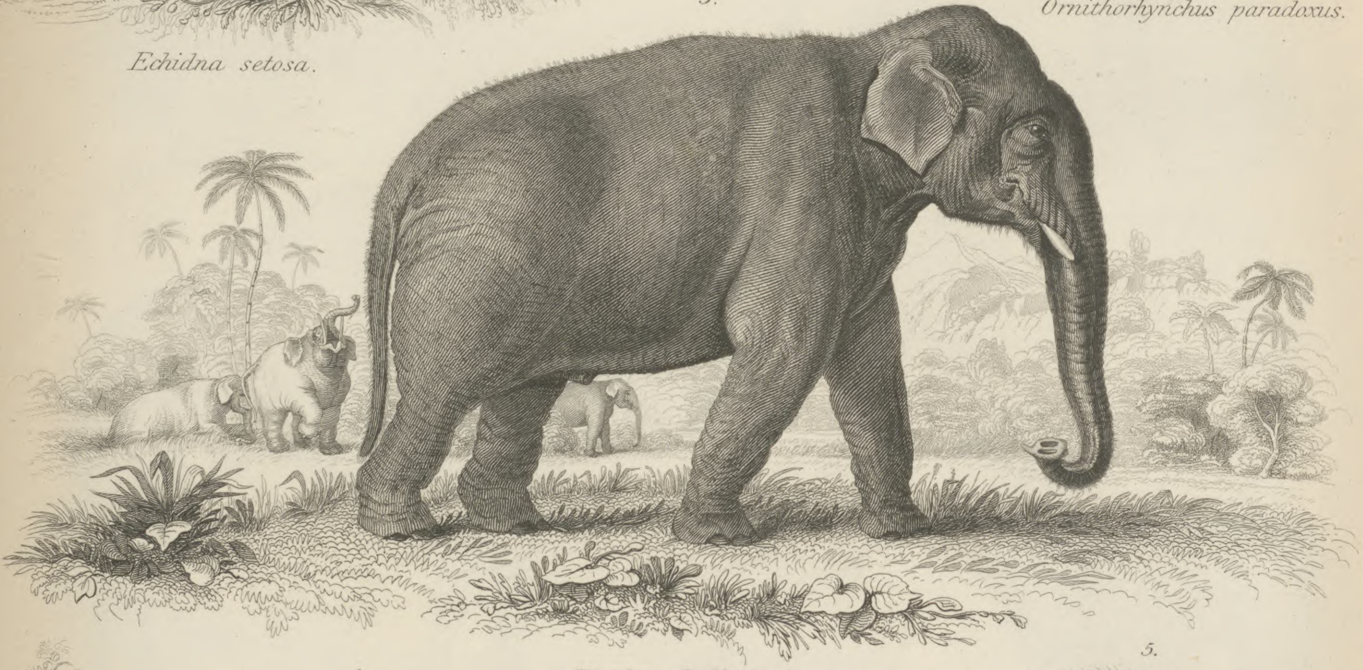
Echidna setosa.

2.



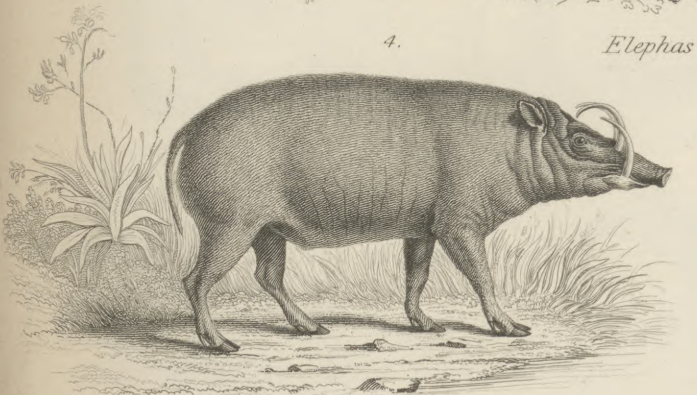
Ornithorhynchus paradoxus.

3.



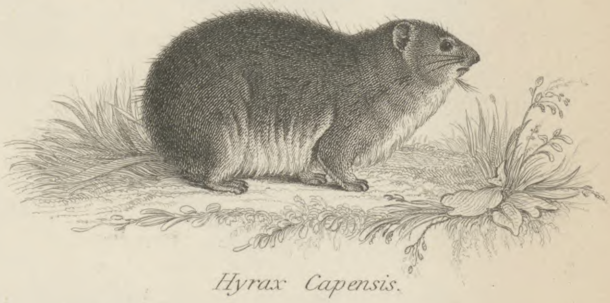
Elephas Indicus.

4.



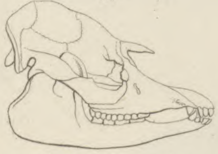
Sus babyrussa.

5.



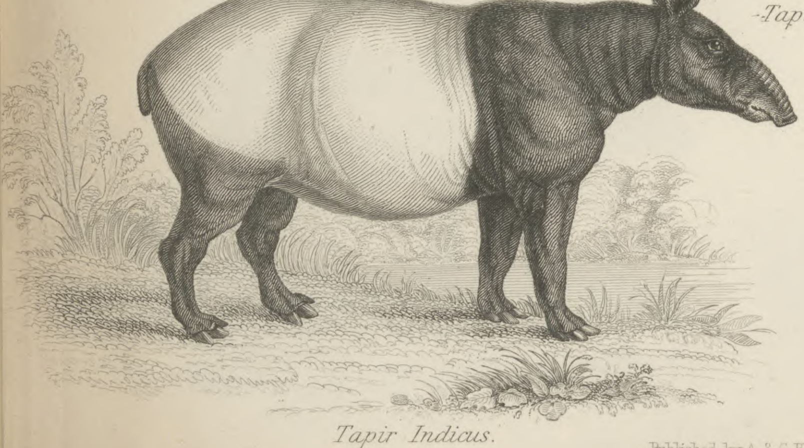
Hyrax Capensis.

6.



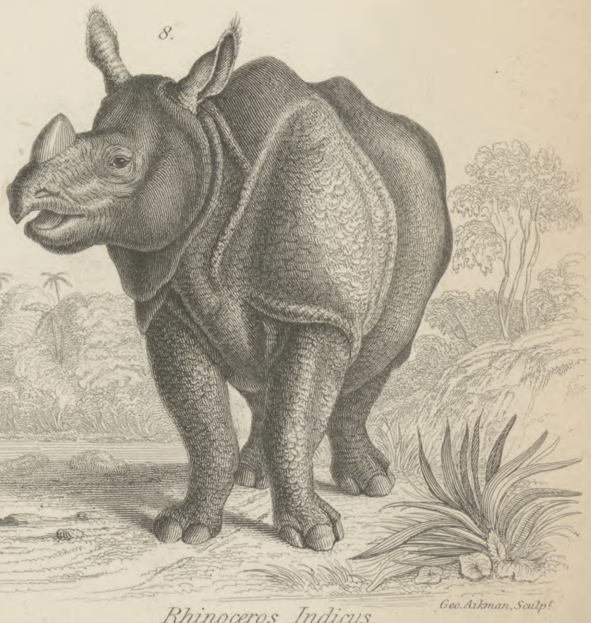
Cranium of Tapir Americanus.

7.



Tapir Indicus.

8.



Rhinoceros Indicus.

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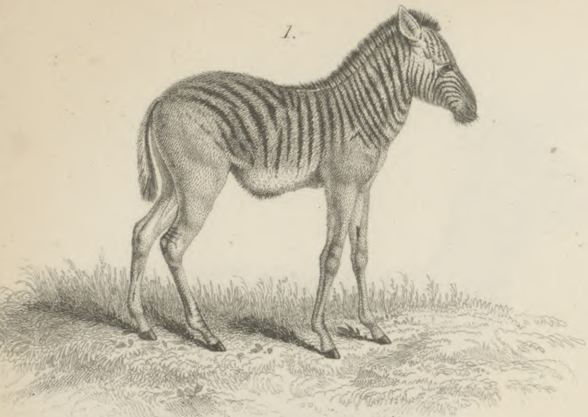
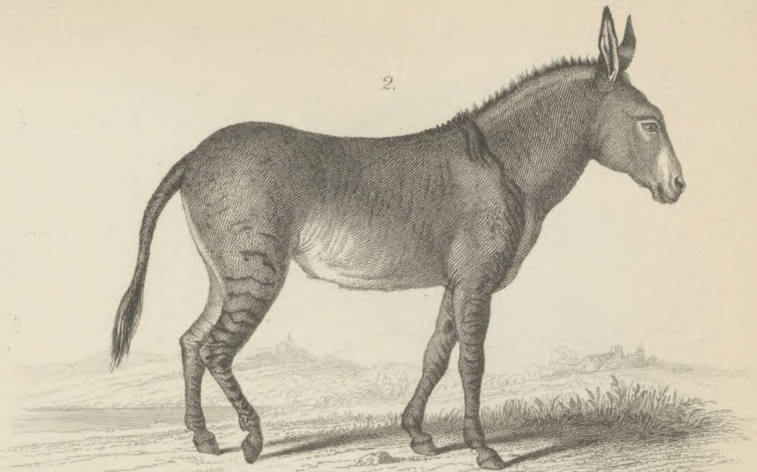
Geo. Aikman, Sculp^t

1.



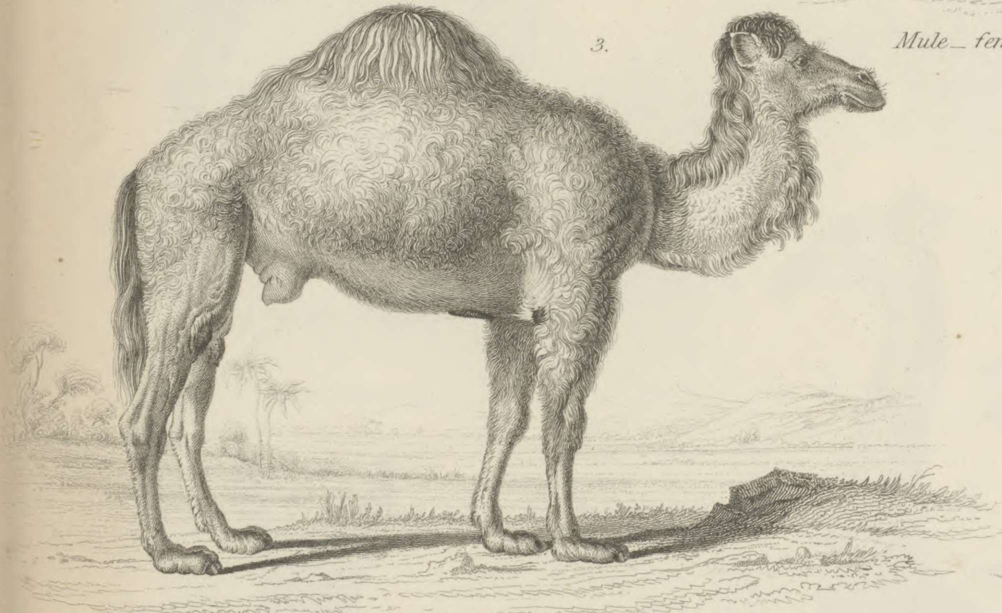
Young of Equus Burchellii.

2.



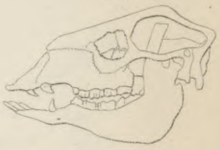
Mule _ female Zebra & Spanish Ass.

3.



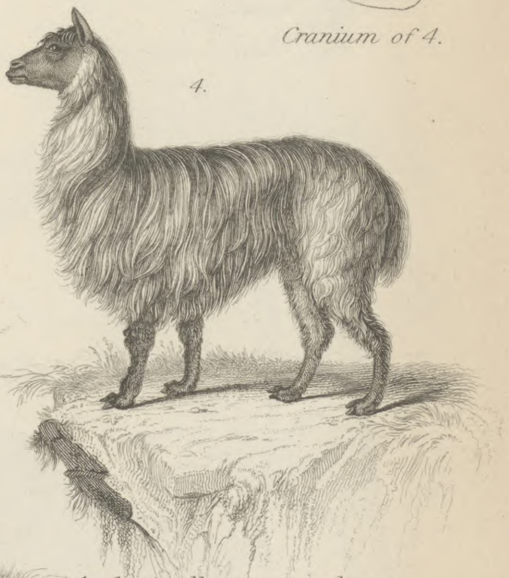
Camelus dromedarius.

5.



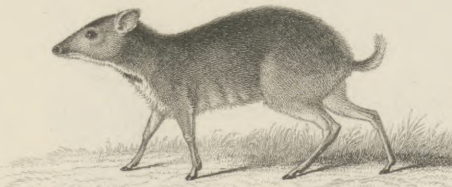
Cranium of 4.

4.



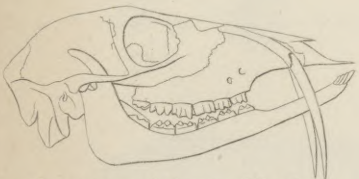
Auchenia llacma, var. alpaca.

7.



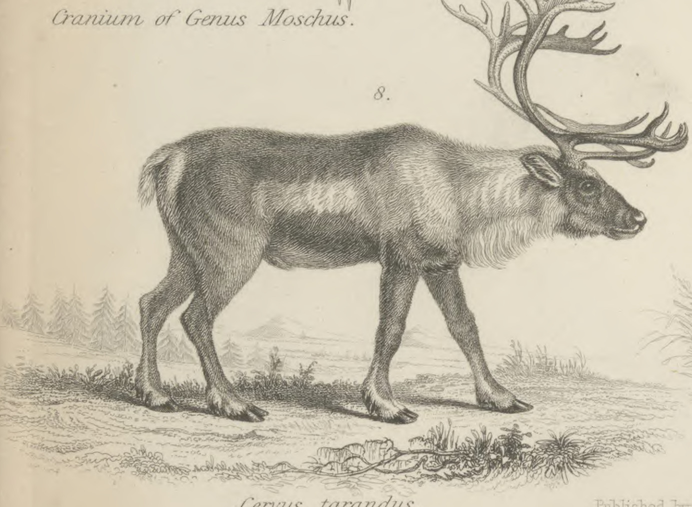
Moschus Javanicus.

6.



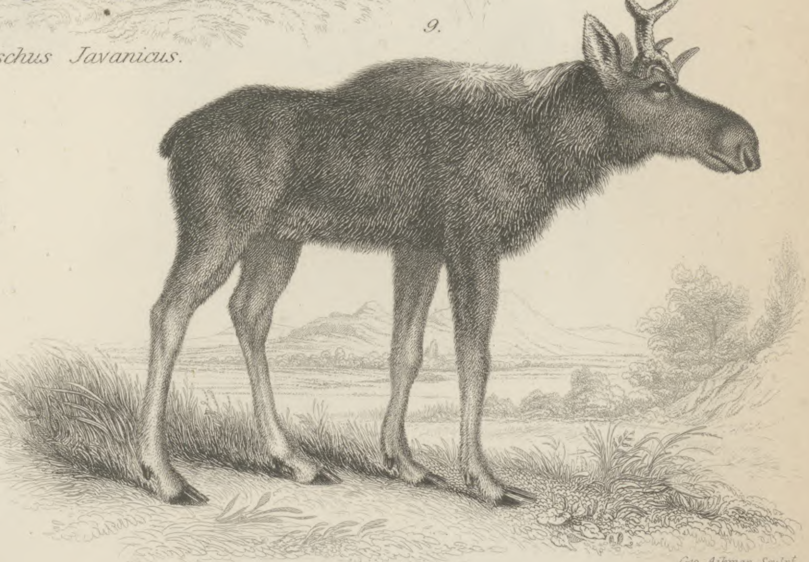
Cranium of Genus Moschus.

8.



Cervus tarandus.

9.



Cervus alces.

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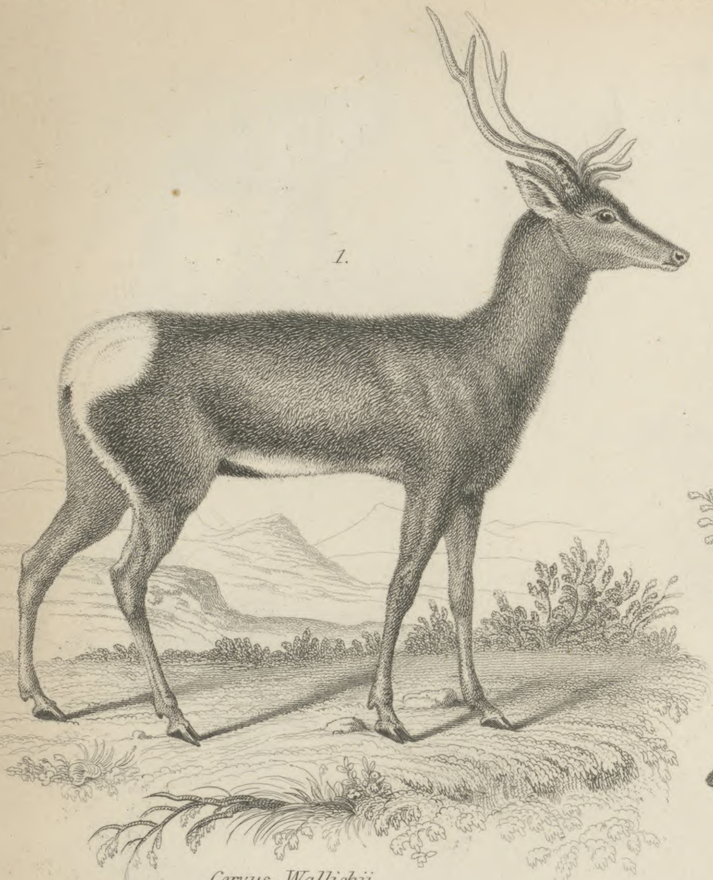
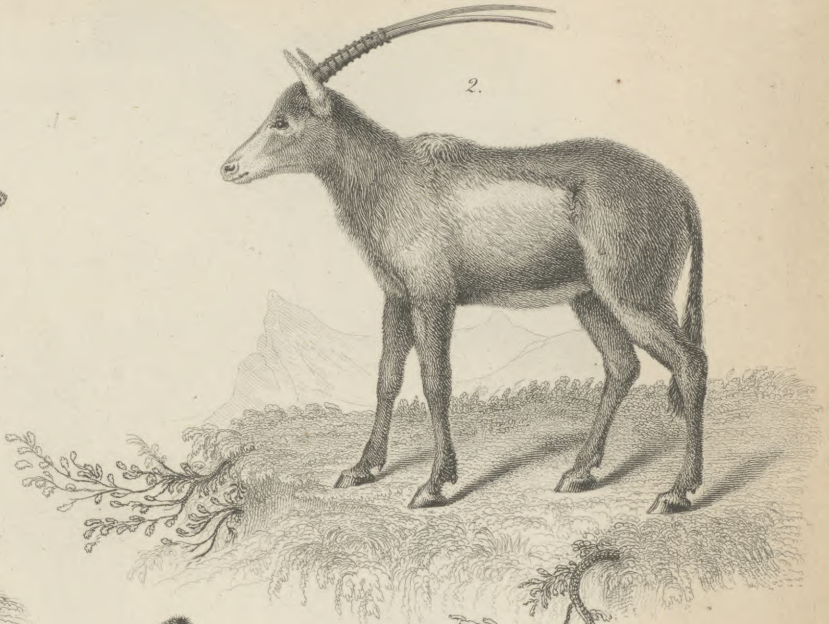
Geo Aikman, Sculpt.



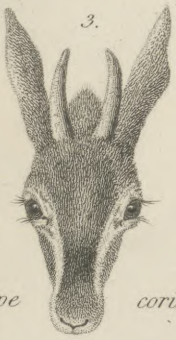
1.

Cervus Wallichii.



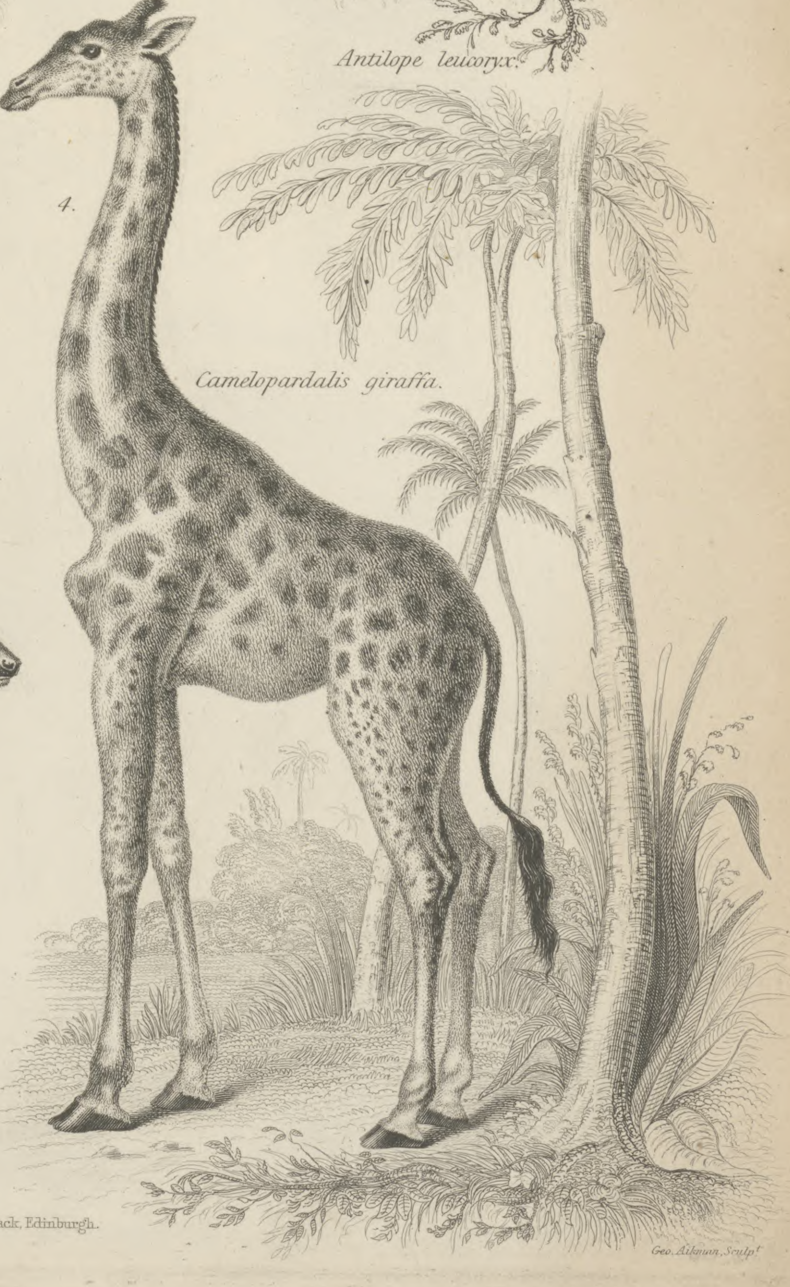
2.

Antilope leucoryx.



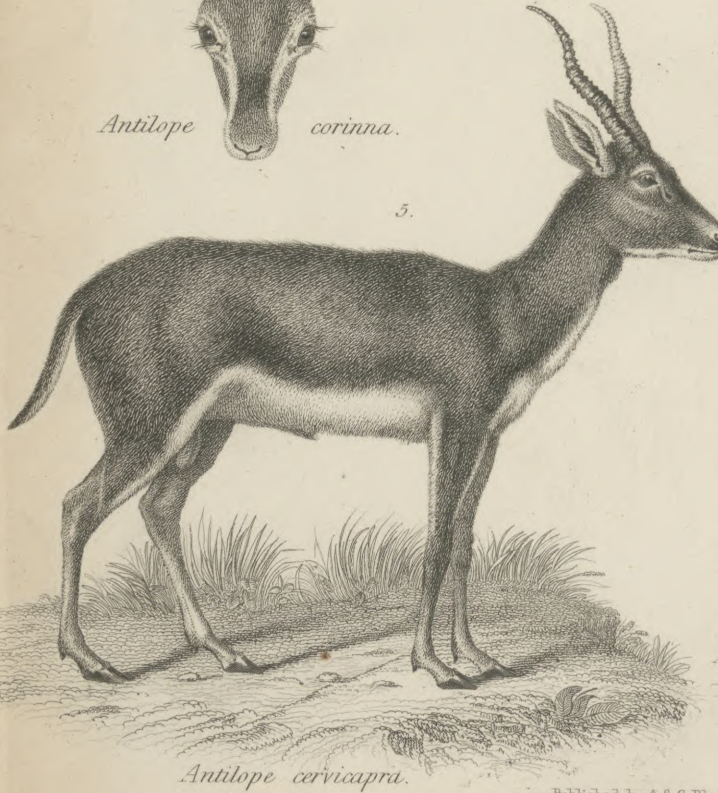
3.

Antilope corinna.



4.

Camelopardalis giraffa.



5.

Antilope cervicapra.

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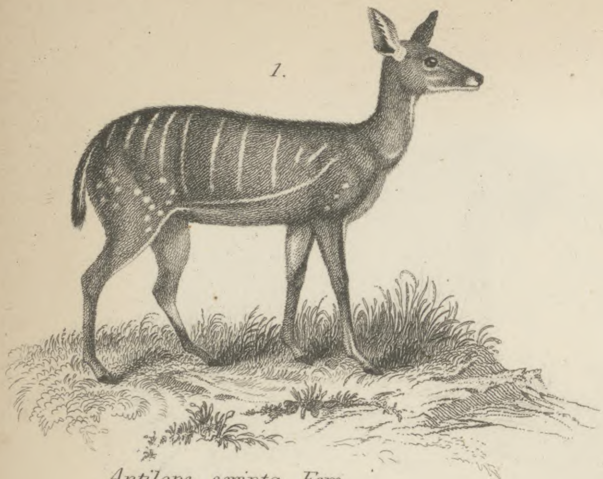
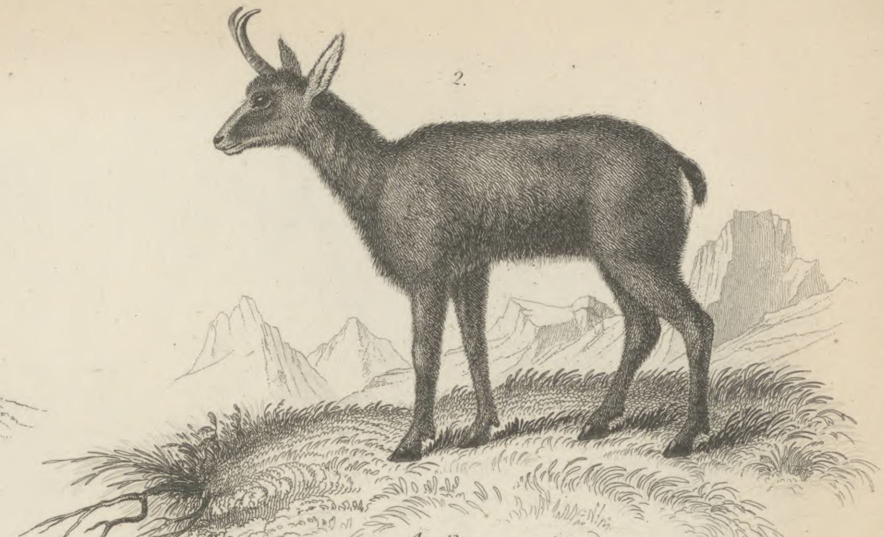
Geo. Aikman, Sculpt.

1.



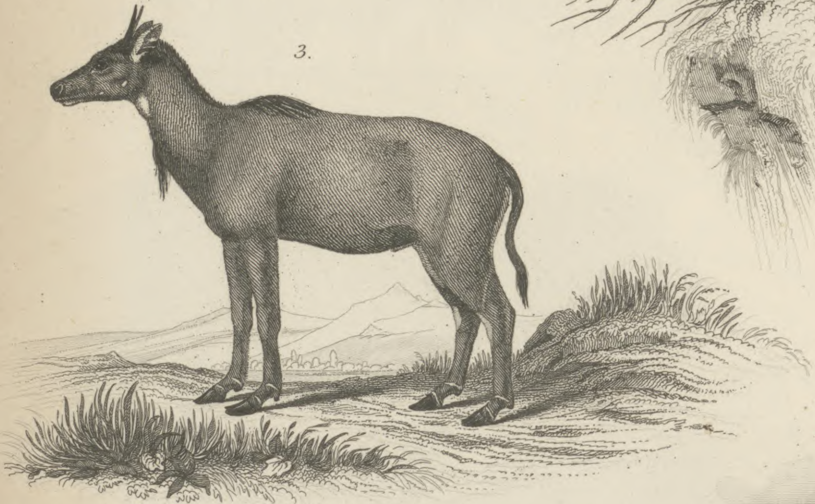
Antilope scripta. Fem.

2.



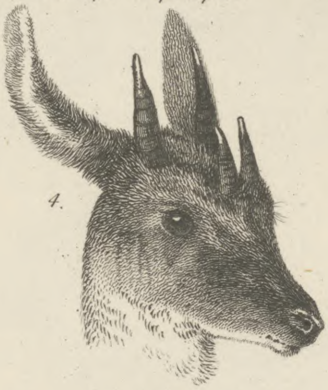
Antilope rupicapra.

3.



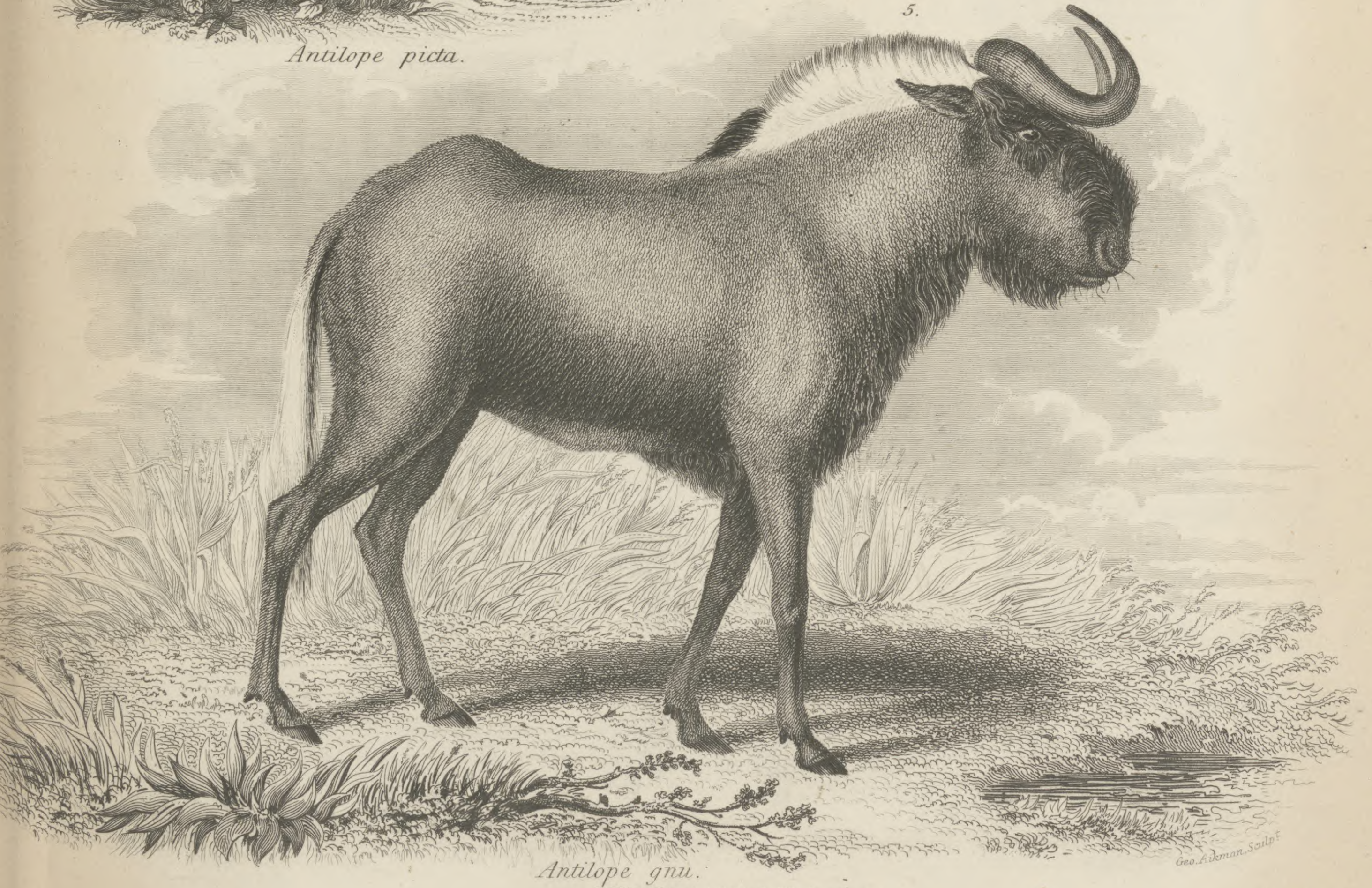
Antilope picta.

4.



Antilope chickara.

5.



Antilope gnu.

Geo. Aikman Sculpt.

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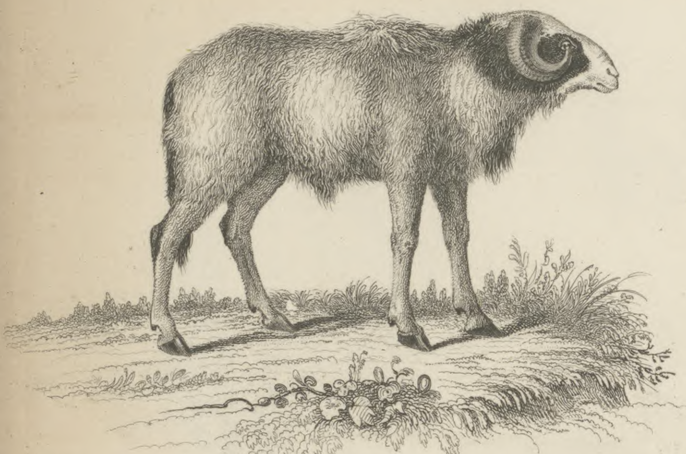
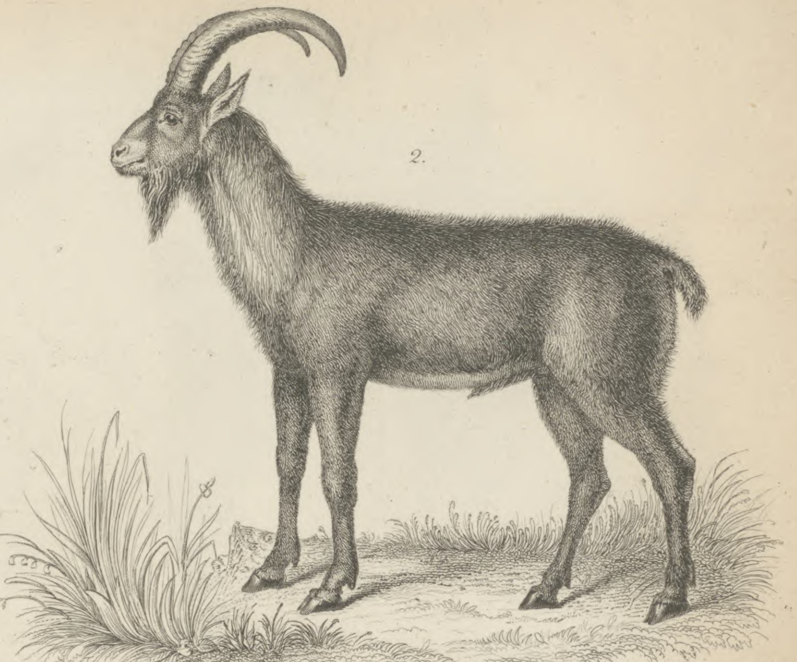
MAMMALIA.

1.



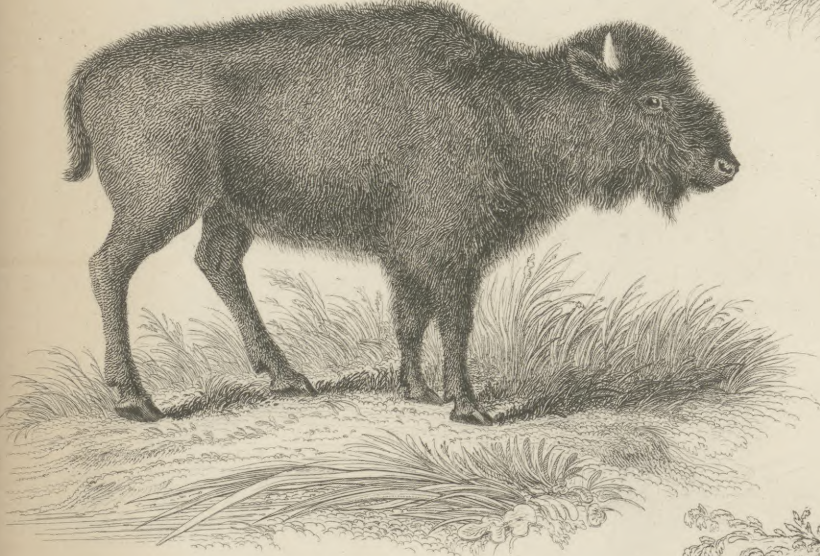
Ovis aries, var. longipes.

2.



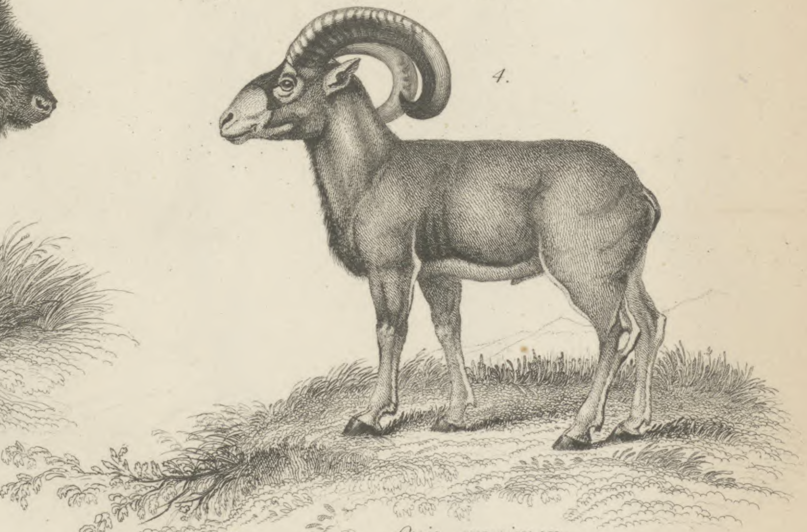
Capra ægagrus.

3.



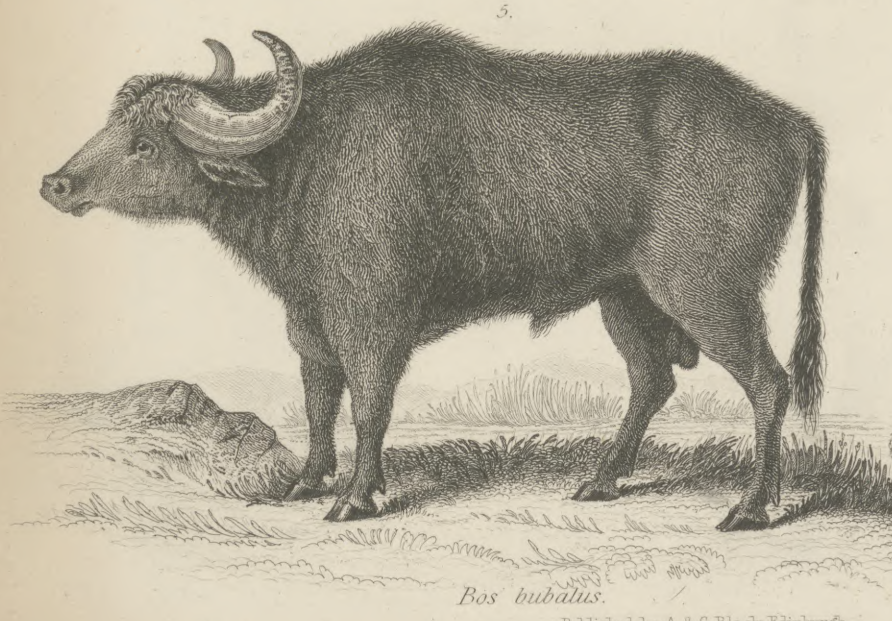
Bos bison, Americanus.

4.



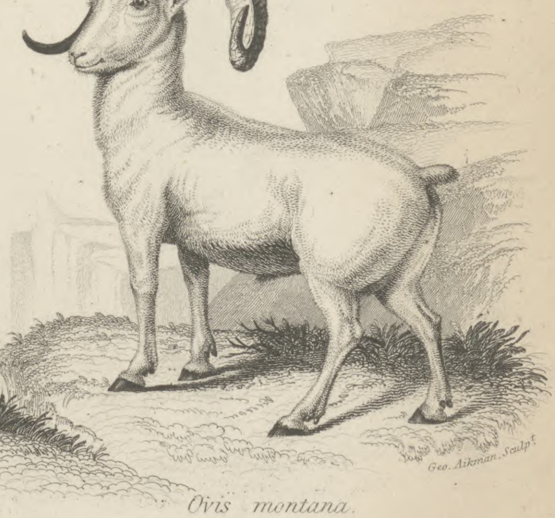
Ovis musimon.

5.



Bos bubalus.

6.



Geo. Aikman, Sculpt.

Ovis montana.

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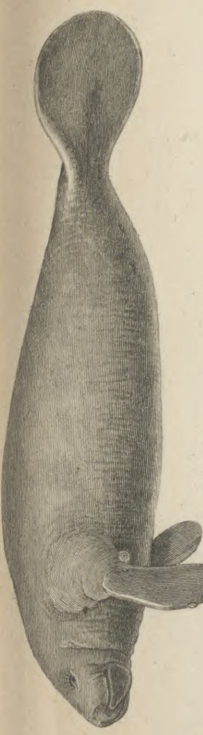
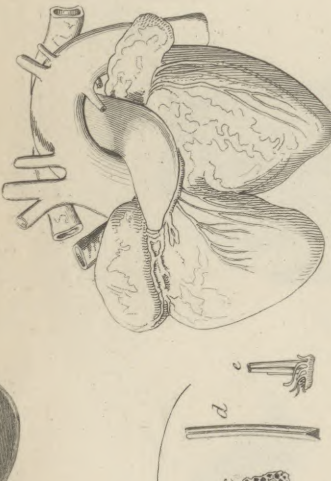
MAMMALIA.

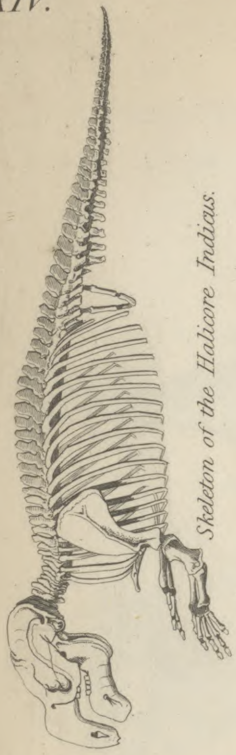
Geo. Aikman, Sculpt.



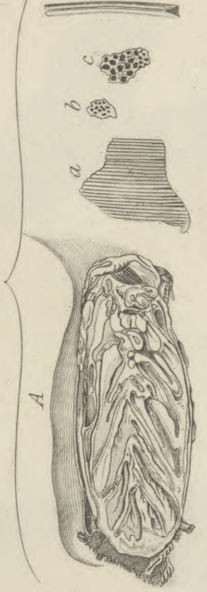
Manatus Americanus.



2. Heart of Halicore Indicus and Stellerus.



3. Skeleton of the Halicore Indicus.



4. Tooth of the Stellerus.

5. Teeth of the Inia.

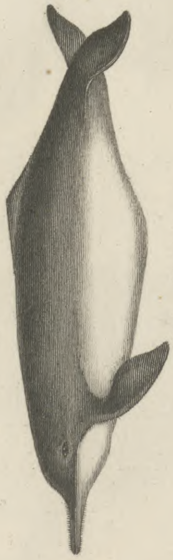
6. Facial line of Genus Soosoo.

7. Genus Delphinorhynus.

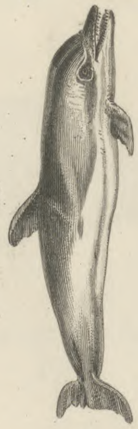
8. Genus Delphinus.

9. Genus Phocæna.

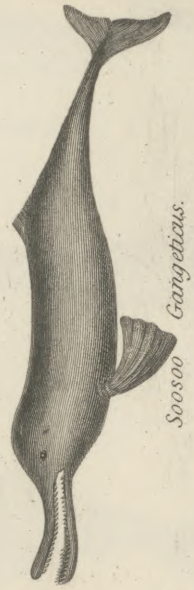
10. Genus Globicephalus.



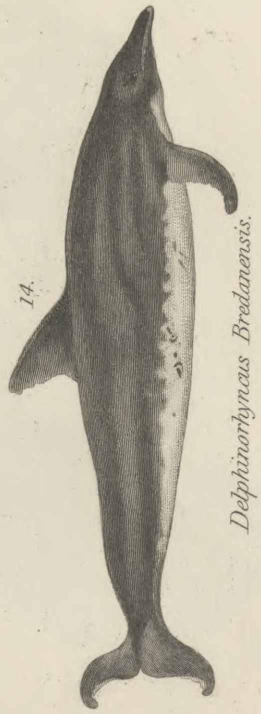
11. Inia Boliviensis.



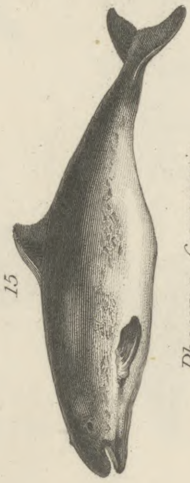
12. Delphinus Delphis.



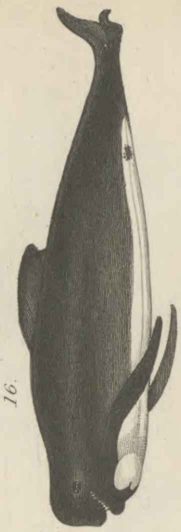
13. Soosoo Gangeticus.



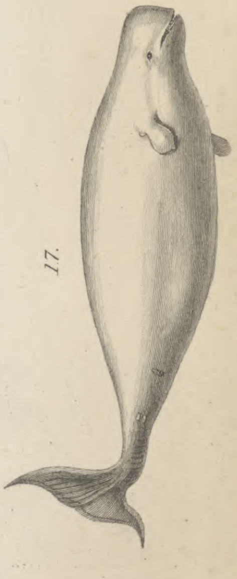
14. Delphinorhyncus Bredanensis.



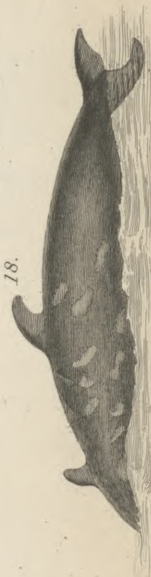
15. Phocæna Communis.



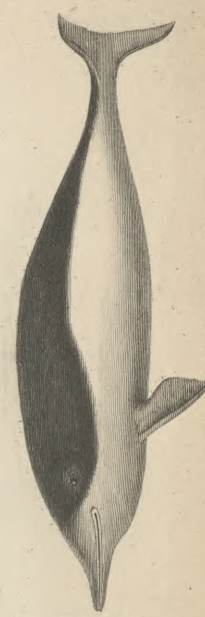
16. Globicephalus Deductor.



17. Beluga Arctica.



18. Oxypterus Rhinoceros.



19. Delphinapterus Peronii.

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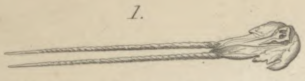
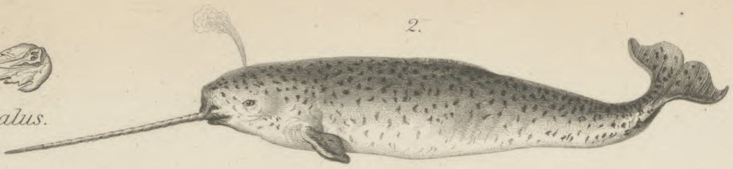
MAMMALIA.

1.



Tusks of the Narwhalus.

2.



Narwhalus Microcephalus.

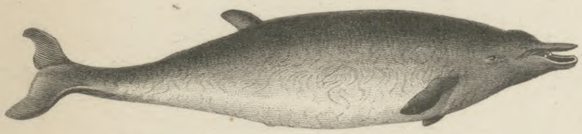
3.

Wind-pipe of Delphinus.

4.

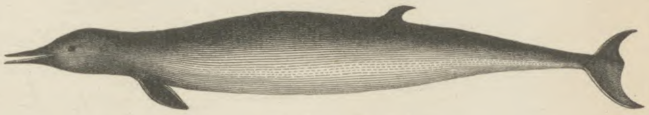
Wind-pipe of Narwhalus.

5.



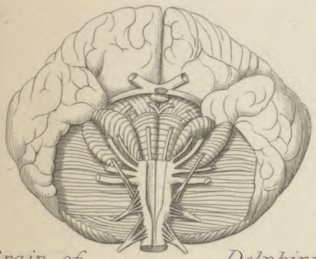
Diodon Sowerbii.

6.



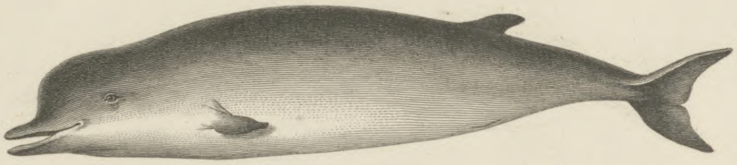
Aodon Dalei.

7.



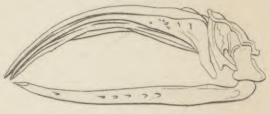
Brain of Delphinus.

8.



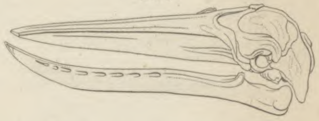
Hyperoodon Honfleuriensis.

9.



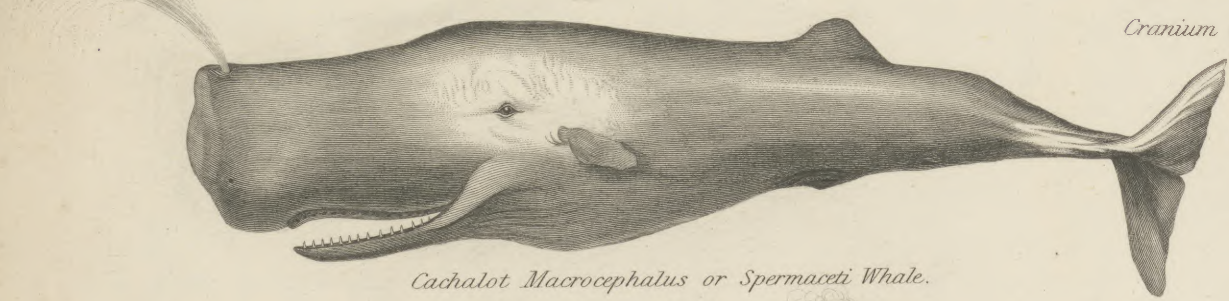
Cranium of Mysticetus.

10.



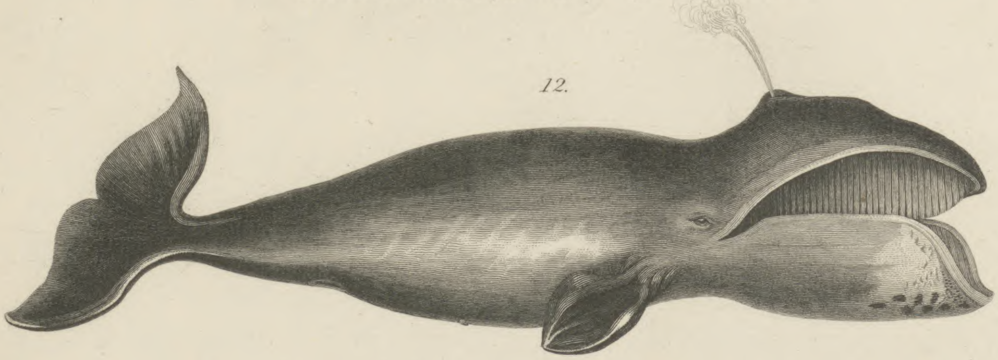
Cranium of Rorqualus.

11.



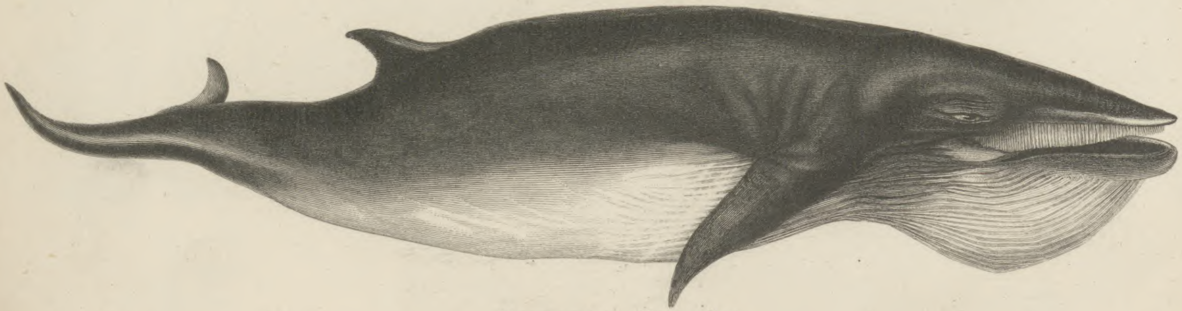
Cachalot Macrocephalus or Spermaceti Whale.

12.



Balæna Mysticetus or Greenland Whale.

13.



Rorqualus Rostratus.

Geo. Aikman, Sculpt.

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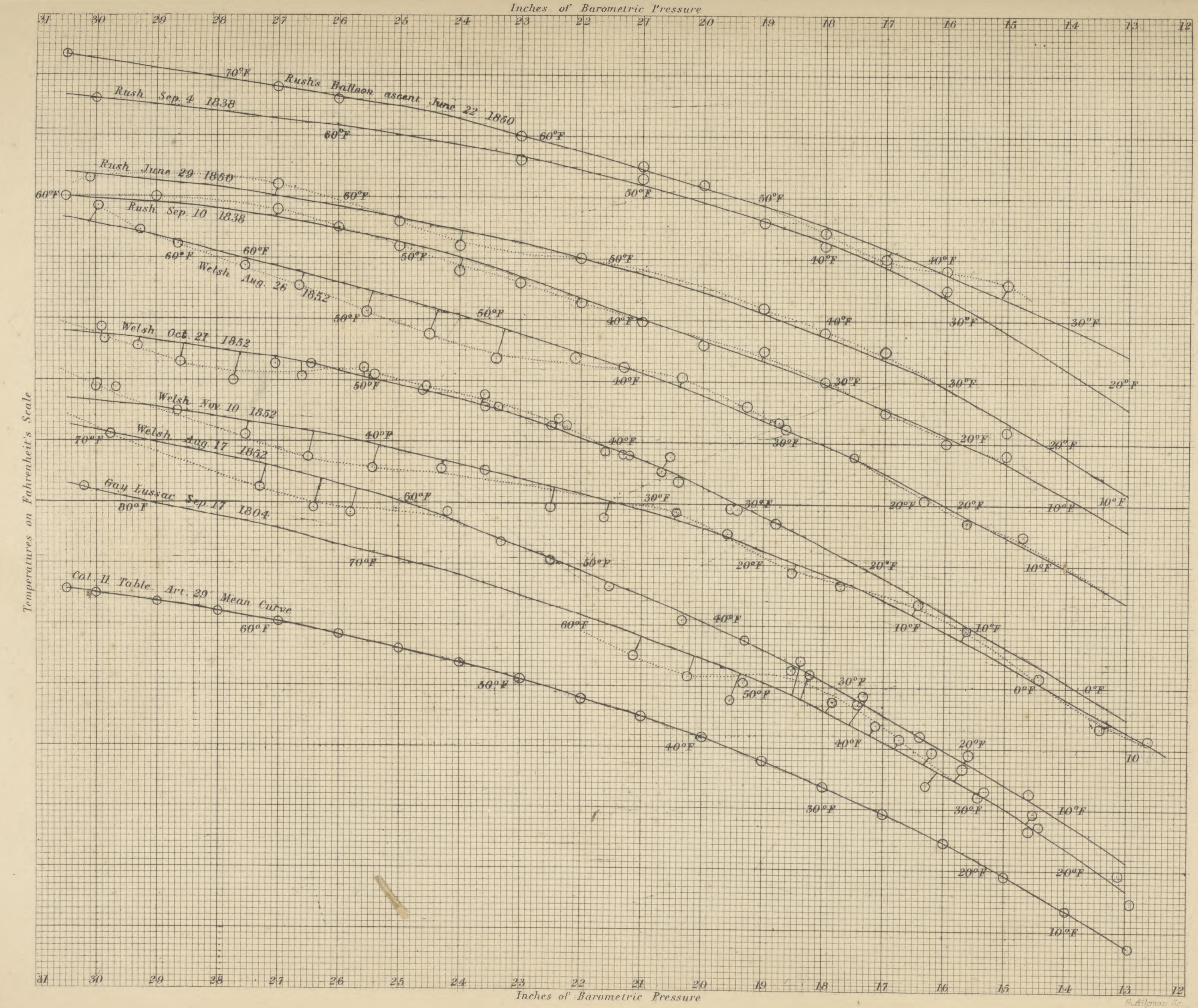
METEOROLOGY.

PLATE XVIII.



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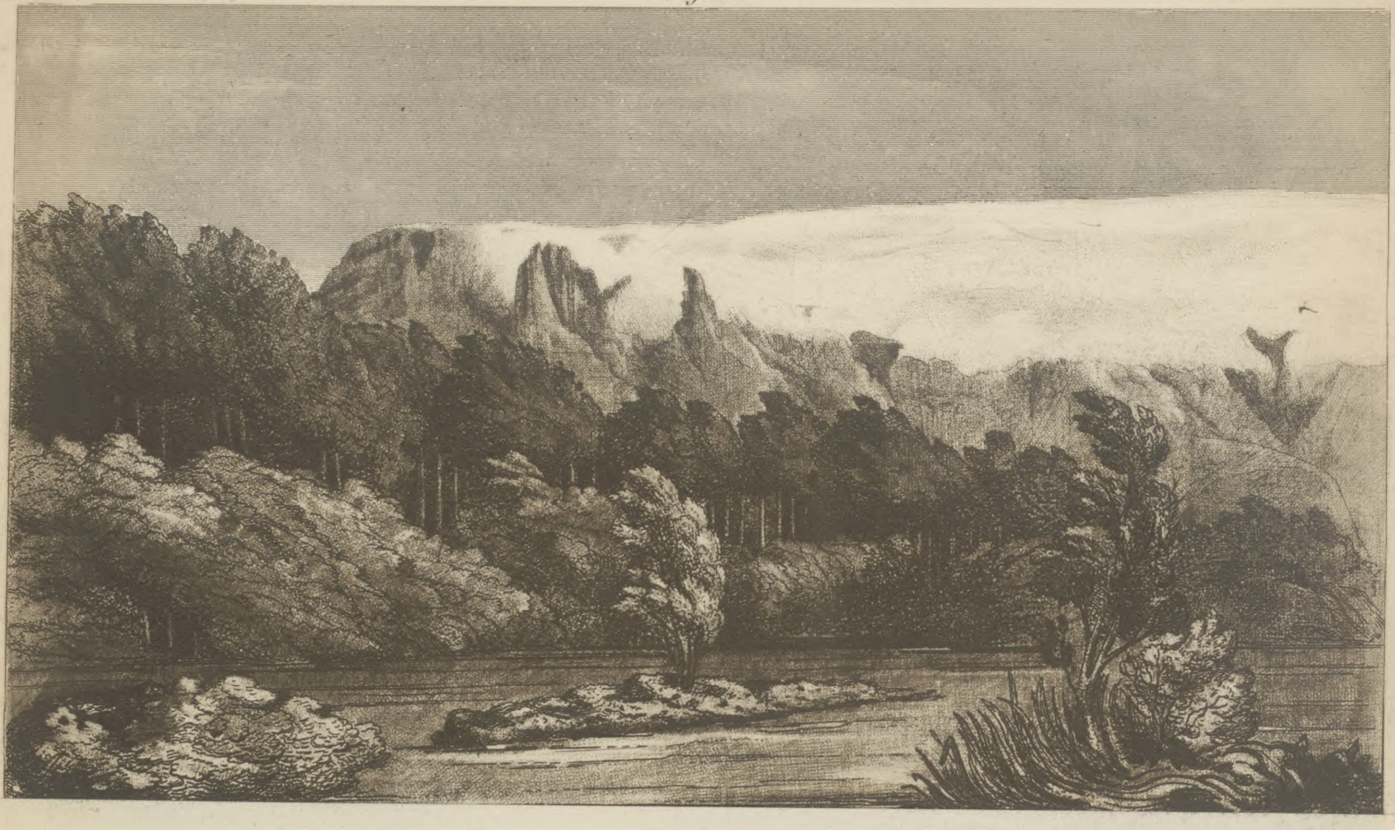
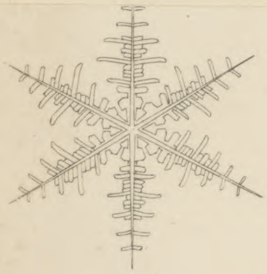
VOL. XIV. METEOROLOGY. *PLATE XVIII.*

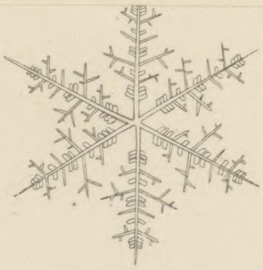
Fig. 1

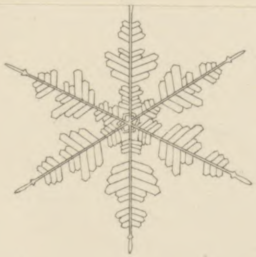


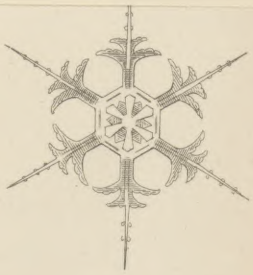
NOTICE.

Plate XVIII., containing Figs. 1 to 15, should have been numbered Plate XIX.









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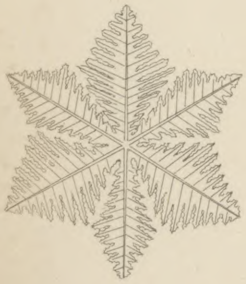

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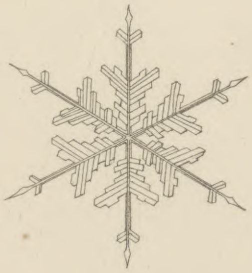

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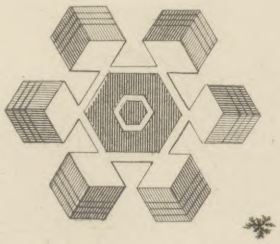
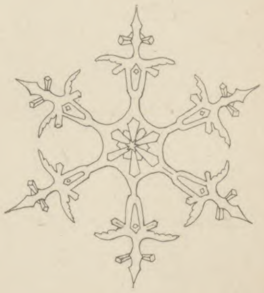


15



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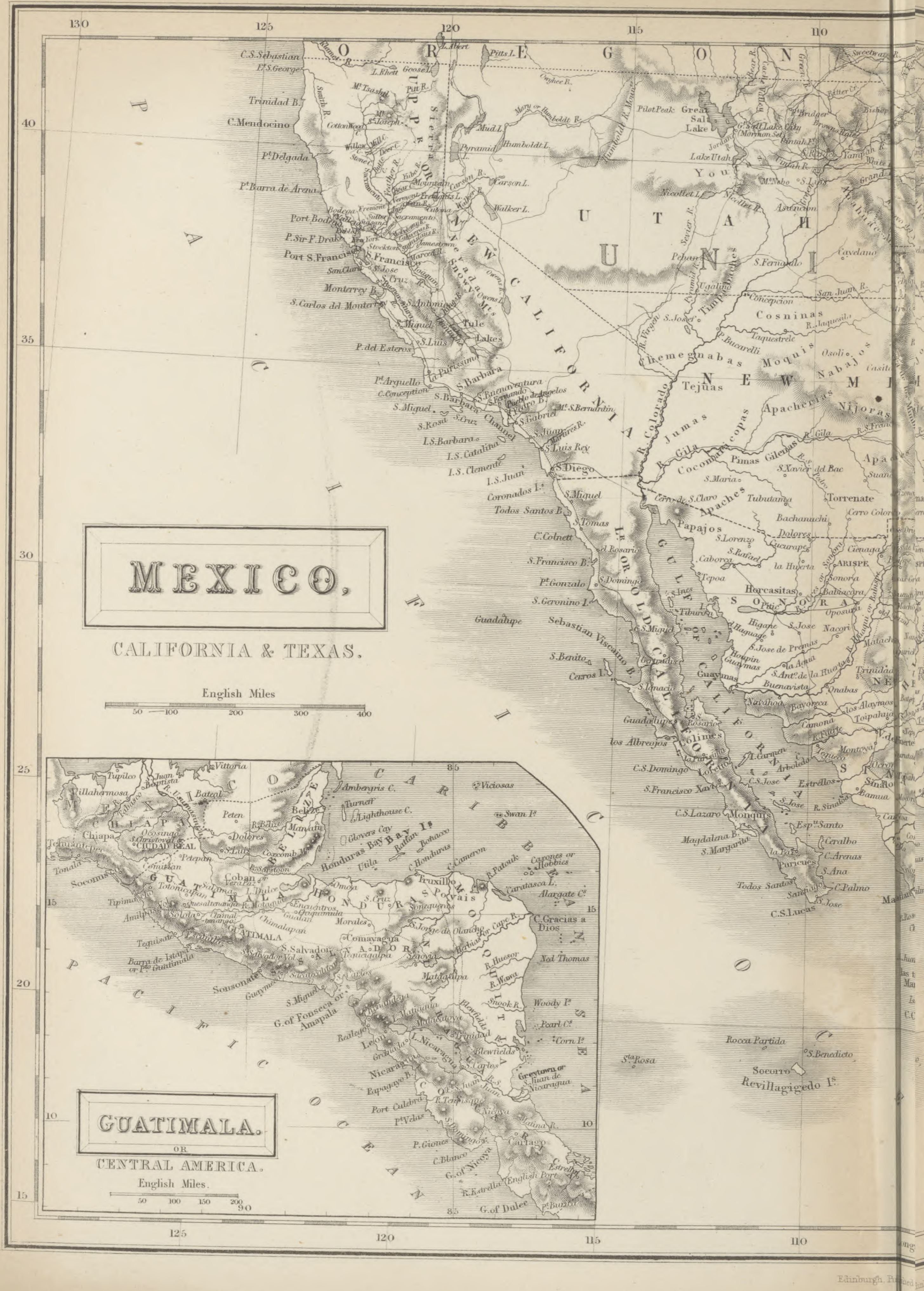


MEXICO,

CALIFORNIA & TEXAS.

English Miles

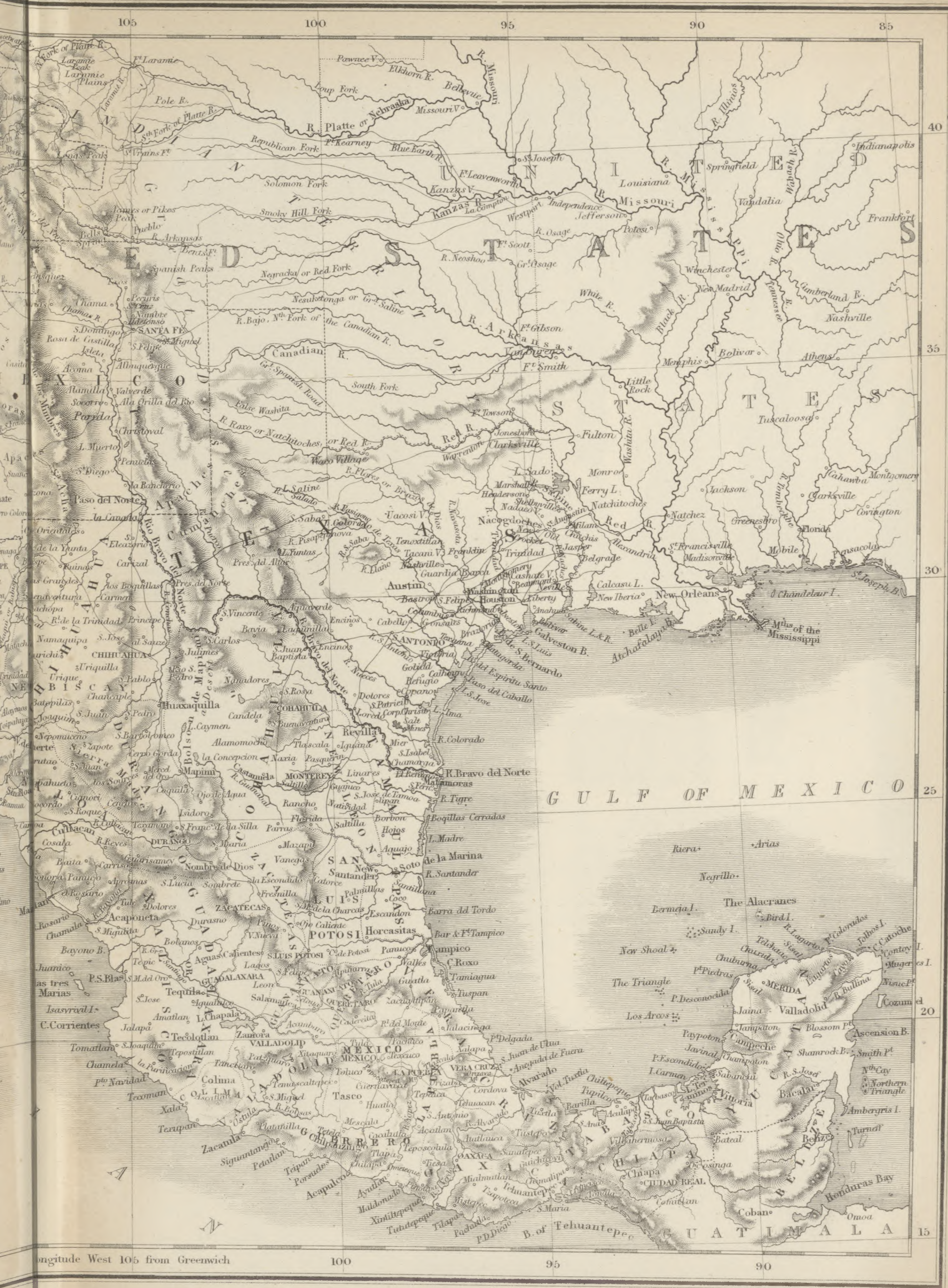
GUATIMALA.

OR

CENTRAL AMERICA.

English Miles.

Edinburgh, Pu



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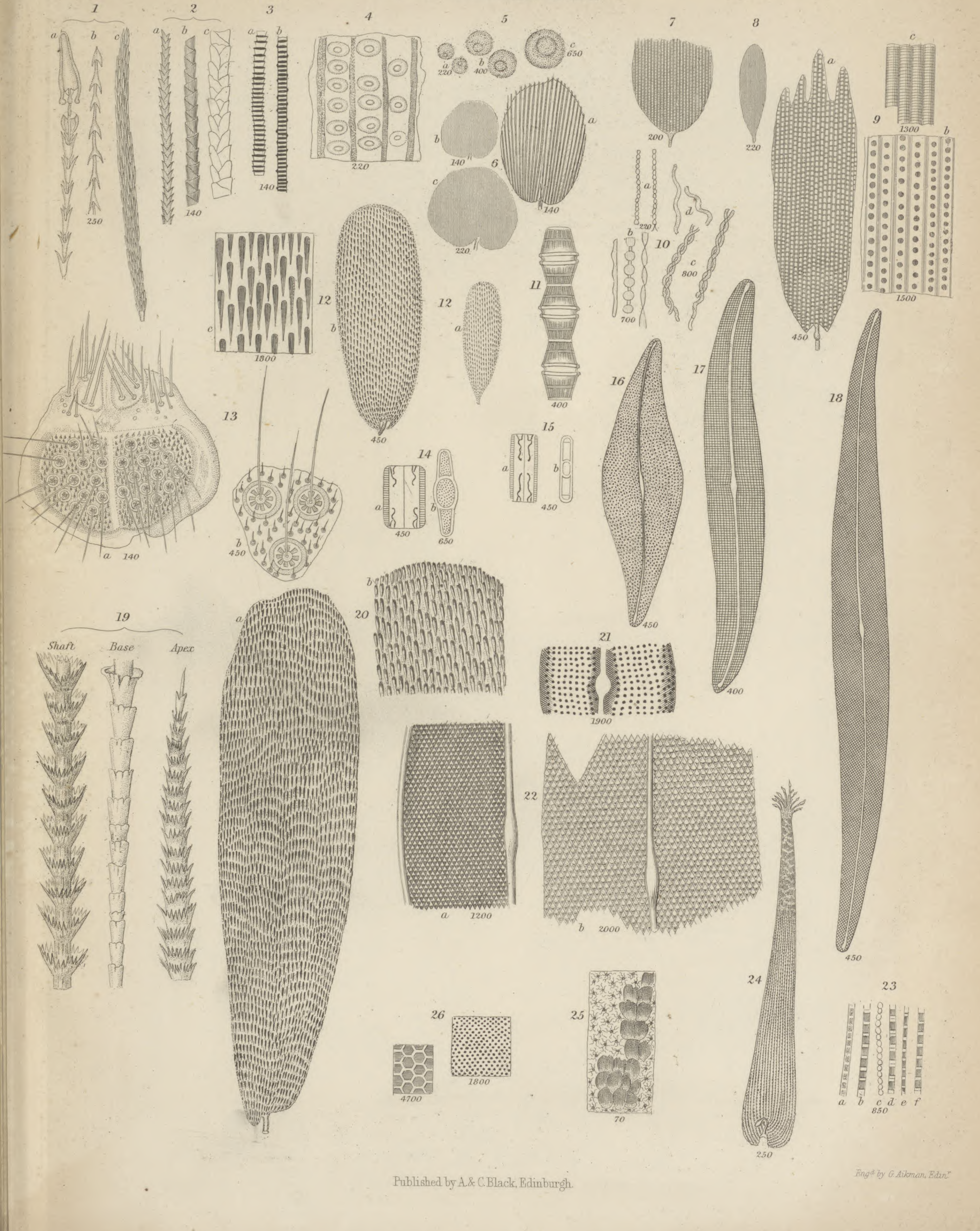
TEST AND MICROSCOPIC OBJECTS.



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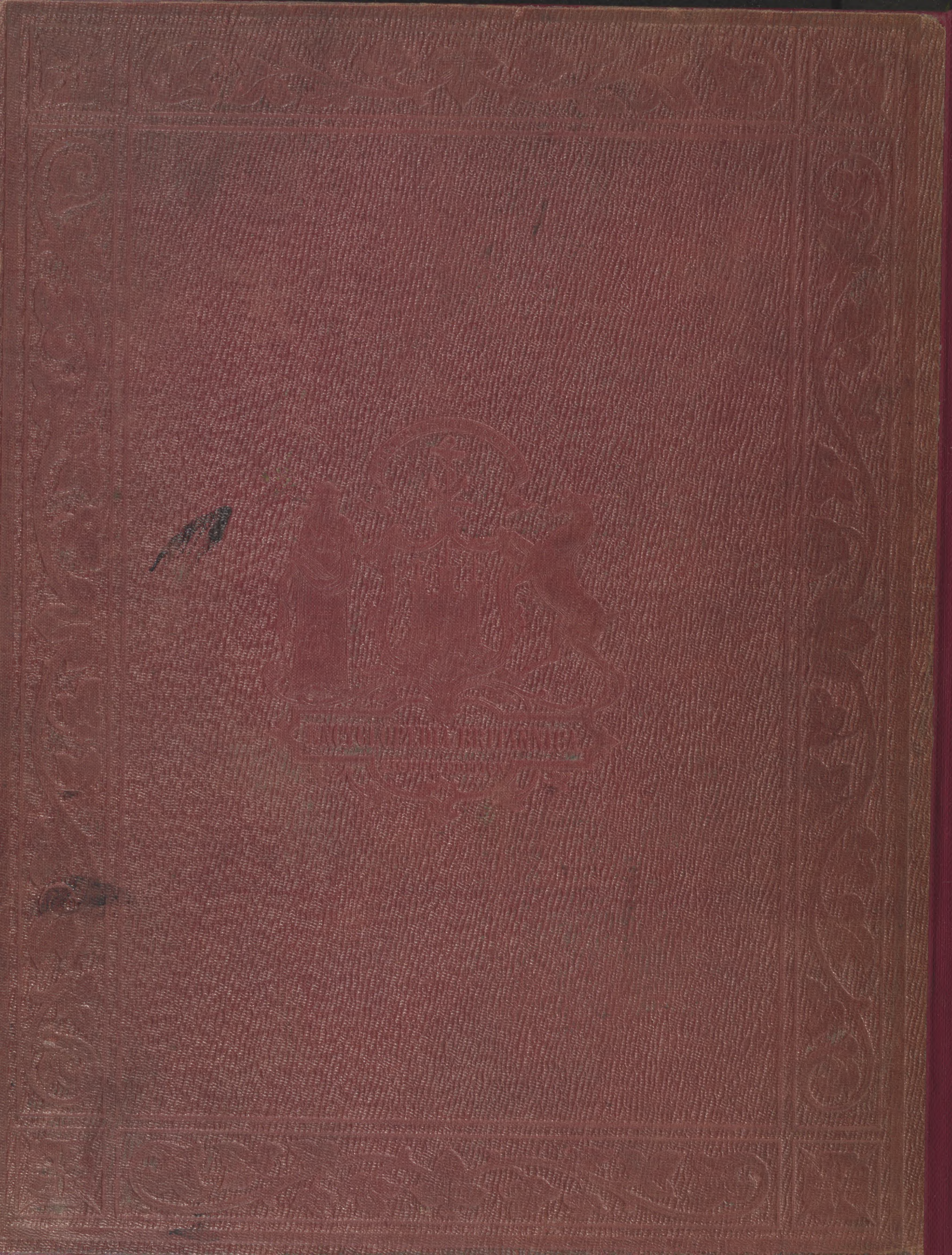
14

*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